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Full Length Research Paper

Effect of micronutrient application in coriander (*Coriandrum sativum* L.) cv.CO_4

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The field experiments were conducted during two seasons to find out the role of micronutrients on growth, seed yield and quality in coriander cv. CO_4. The soil of the experimental site was calcareous. Micronutrient deficiencies are common in soils that have a high calcium carbonate ($CaCO_3$) due to reduced solubility at alkaline pH values. Micronutrients such as iron (Fe), zinc (Zn), copper (Cu) and manganese (Mn) were applied in their sulphate form ($FeSO_4$, $ZnSO_4$, $CuSO_4$ and $MnSO_4$, respectively). The effect of both soil application (25 kg/ha) and foliar spray (0.5%) of micronutrients at 30 and 45 days after sowing were studied individually. Foliar spray of 0.5% $FeSO_4$ induced the highest growth rates in terms of net assimilation rate (0.085 mg $g^{-1}day^{-1}$in rabi and 0.063 mg $g^{-1}day^{-1}$ in kharif) and crop growth rate (7.52 mg m^{-2} day^{-1}in rabi and 7.78 mg m^{-2} day^{-1}in kharif). Maximum number of umbels per plant (33.7 in rabi and 13.8 in kharif) and highest seed yield per hectare (623.3 kg in rabi and 599.9 kg in kharif) were observed for the foliar application of 0.5% $FeSO_4$ if compared to other treatments. Foliar application of iron and zinc exhibited significant effect on resultant seed quality parameters. The study revealed the need for application of micronutrients in maximum realization of yield and quality of the coriander seed crop in calcareous soils.

Key words: Coriander, foliar spray, growth, iron, micronutrients, quality, seed yield, zinc.

INTRODUCTION

The seed spices constitute an important group of agricultural commodities. Among the seed spices, coriander is the most important spice crop with multipurpose utility. Coriander (*Coriandrum sativum* L.) is an annual herb of the apiaceae family. For adequate plant growth and production, micronutrients are needed in small quantities; however, their deficiencies cause a great disturbance in the physiological and metabolic processes in the plant. Micronutrients application plays an important role in the production of good quality and high yield of crops (Amjad et al., 2014). The role of micronutrients in photosynthesis, N-fixation, respiration and other metabolic processes of the plant is well documented (Naga Sivaiah et al., 2013). The effects of micronutrient foliar fertilizer on the promotion of growth and production of some medicinal and aromatic plants were observed by several researchers (Nasiri et al., 2010; Joynul et al., 2012; Mazaheri et al., 2013). Application of micronutrients significantly influenced the number of branches, umbels per plant, seeds per umbel and seed yield of coriander (Kalidasu et al., 2008). Improved fertilizer management is required to grow crops

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successfully on calcareous soils. Iron, Zinc, Manganese and Copper deficiencies are common in soils that have a high calcium carbonate ($CaCO_3$) due to reduced solubility at alkaline pH values. The present study was undertaken to assess the potential of micronutrients in the improvement of seed yield and quality of coriander cv.CO_4.

MATERIALS AND METHODS

Pure seeds of coriander (*C. sativum* L.) cv. CO_4 which formed the base material for the study were obtained from the Department of Spices and Plantations Crops, TNAU, Coimbatore. The field experiment was conducted at the orchard of HC & RI, Coimbatore in two seasons (Rabi, 2009; Kharif, 2010). Before sowing, physical and chemical properties of the soil of the experimental site were determined (Jackson, 1973). The soil of the experimental site was clayey textured and calcareous with a pH of 8.10. The results of soil chemical analysis were as follows: electrical conductivity (ds/m) = 0.14; available nitrogen (kg/ha) = 207; available phosphorus (kg/ha) = 15.4; available potassium (kg/ha) = 849; copper (ppm) = 2.22, manganese (ppm) = 7.50; iron (ppm) = 4.16 and zinc (ppm) = 1.06. Seeds were sown in plot size of 3 × 1.5 m with a spacing of 15 × 10 cm following randomized block design with 9 treatments involving four micronutrients viz. iron (Fe), zinc (Zn), copper (Cu) and manganese (Mn) applied through soil (25 kg/ha) and foliar spray (0.5%) individually at 30 and 45 days after sowing (DAS) and three replications. The details of treatments are as follows:

M 1 - Control (NPK)
M 2 - Soil application of $ZnSO_4$ @ 25 kg/ha
M 3 - Foliar application of $ZnSO_4$ @ 0.5%
M 4 - Soil application of $FeSO_4$ @ 25 kg/ha
M 5 - Foliar application of $FeSO_4$ @ 0.5%
M 6 - Soil application of $CuSO_4$ @ 25 kg/ha
M 7 - Foliar application of $CuSO_4$ @ 0.5%
M 8- Soil application of $MnSO_4$ @ 25 kg/ha
M 9 - Foliar application of $MnSO_4$ @ 0.5%

All other cultural practices were followed according to standard recommendations for the locality. Five randomly selected plants in each treatment and in each replication were selected for recording the observations. Observations on growth, seed yield and resultant seed quality characteristics were taken.

The biometric characters like net assimilation rate (NAR) and crop growth rate (CGR) were calculated for different plant growth stages (30, 40, 50 and 60 days after sowing). The sample means were then taken as representative of the population. Five plants were randomly selected in each treatment for recording dry matter production. Plants were oven dried at 70°C till uniform constant weight was obtained. Completely dried samples were weighed and the dry weight of different plant parts was expressed in g per plant. NAR was calculated using the following formula (Williams, 1946) and expressed as mg $g^{-1}day^{-1}$.

$$NAR = \frac{\log_e L_2 - \log_e L_1}{L_2 - L_1} \times \frac{w_2 - w_1}{t_2 - t_1}$$

Where t_1, t_2 - days of observation; L2, L_1- leaf dry weight at t_2 and t_1; w_2, w_1 - whole plant dry weight at t_2 and t_1.

Crop growth rate (CGR) was calculated using the following formula (Watson, 1952) and expressed as mg m^{-2} day^{-1}.

$$CGR = \frac{w_2 - w_1}{P\,(t_2 - t_1)}$$

Where, t_1, t_2 - days of observation; w_2, w_1 - whole plant dry weight at t_2 and t_1; P - spacing in m^2.

Seed quality parameters such as germination (ISTA, 2003), vigour index (Abdul–Baki and Anderson, 1973), protein content (Ali-Khan and Youngs, 1973) and essential oil content (ASTA, 1968) were also determined in the harvested seeds. The data was analysed for 'F' test of significance following the statistical methods described by Panse and Sukhatme (1985).

RESULTS AND DISCUSSION

Micronutrients played a vital role in the growth and development of coriander cv. CO_4. Among the two methods (soil application and foliar spray) of application of micro nutrients, foliar spraying was more effective. The positive influence of foliar application of micronutrients on crop growth may be due to the improved ability of the crop to absorb nutrients, photosynthesis and better sink source relationship as these play vital role in various biochemical processes. These findings are in conformity with the studies of Nasiri et al. (2010).

Foliar spray of 0.5% $FeSO_4$ recorded highest net assimilation rate (0.085 mg $g^{-1}day^{-1}$in rabi and 0.063 mg $g^{-1}day^{-1}$ in kharif) and was followed by foliar spray of 0.5% $ZnSO_4$ (0.056 mg $g^{-1}day^{-1}$in rabi and kharif) (Figure 1). Higher concentrations of iron in the leaves and leaf tips resulted in increased photosynthesis and more chlorophyll formation (Nadim et al., 2012). Crop growth rate refers to the dry matter production in a unit of time. Difference in crop growth rate due to micronutrient application was significant in both seasons. Foliar application of 0.5% $FeSO_4$ recorded highest crop growth rate (7.52 mg m^{-2} day^{-1}in rabi and 7.78 mg m^{-2} day^{-1}in kharif) (Figure 1). Control recorded lowest crop growth rate in both seasons (2.05 in rabi and 2.37 mg m^{-2} day^{-1} in kharif). Iron acts as an important catalyst in the enzymatic reactions of the metabolism and would have helped in larger biosynthesis of photo assimilates thereby enhancing growth of the plants. Besides the function of iron in the metabolism of chloroplast RNA, it is required at several steps in the biosynthetic pathways leading to increase in the biosynthesis materials (produced and accumulated) consequently, the growth was enhanced. Zinc is a component of carbonic anhydrase, as well as several dehydrogenases and auxin production which in turn enhance plant growth. The present study was in accordance with the findings of Said-Al Ahl and Mahmoud (2010), Salmasi et al., (2012) and Abbas (2013). It was also noticed that foliar application of copper initially caused leaves burning which subsequently reduced the CGR.

Among the yield parameters maximum number of umbels (33.7 in rabi and 13.8 in kharif) and the highest

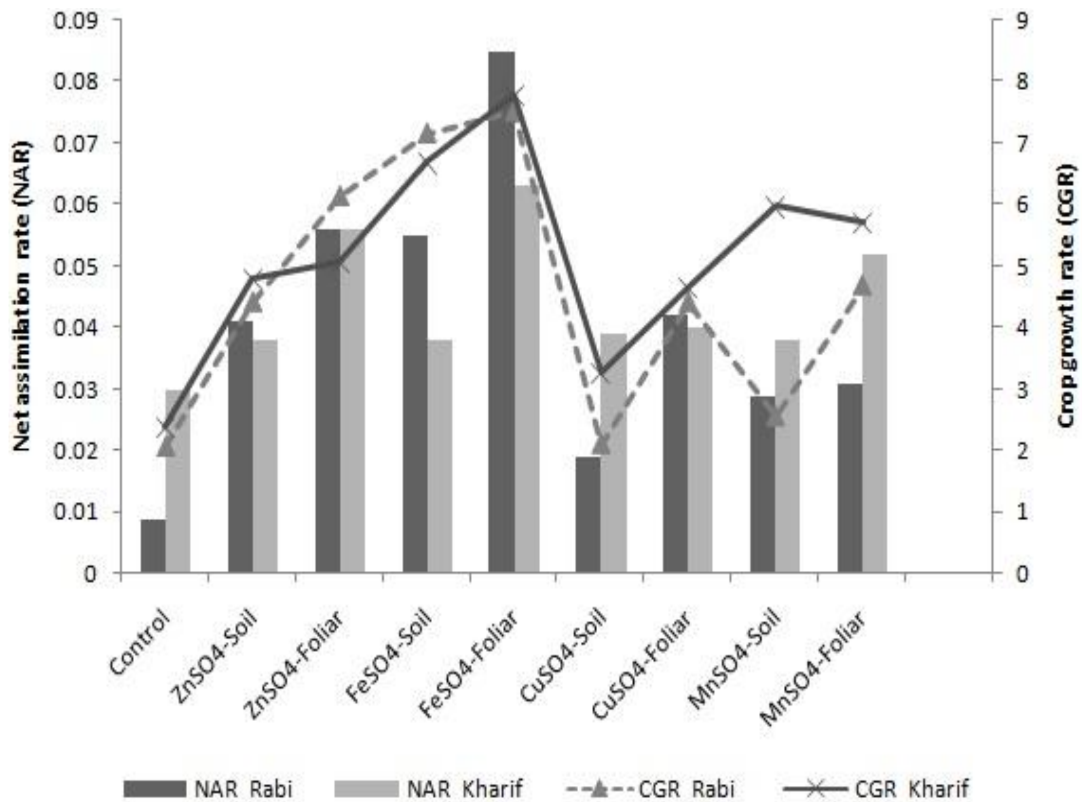

Figure 1. Effect of micronutrient application on growth rate in coriander cv.CO_4.

seed yield ha^{-1} (623.3 kg in rabi and 599.9 kg in kharif) were observed for foliar application of 0.5% $FeSO_4$ compared to other treatments(35% increase over control) (Table 1). The yield improvement may be attributed to higher yield attributing components such as increased plant growth, maximum number of umbels and seeds, which were positively affected by the foliar application of iron. Iron improves photosynthesis and assimilates transportation to sinks and finally increased seed yield (Ebrahimian and Ahmad, 2011). Zeidan et al. (2010) reported that application of Fe, Mn and Zn significantly increased grain yield and yield components of wheat.

Among the seed quality characters, 100 seed weight was higher for the seeds obtained from the plants sprayed with iron (1.55 g in rabi and 1.50 g in kharif) (Table 1). The increase in seed weight might be due to better mineral utilization of plants accompanied with enhancement of photosynthesis, other metabolic activity and greater diversion of food material to seeds (Naga Sivaiah et al., 2013). Foliar spray of zinc and iron recorded higher protein content (12.40 and 12.38%, respectively in rabi and 14.86 and 14.68%, respectively in kharif) (Table 1). Germination was equally enhanced by foliar spray of zinc, iron and copper (90, 93 and 95%, respectively during rabi) and maximum germination was for the seeds of plants sprayed with zinc (94%) during kharif. Foliar spray of $FeSO_4$ recorded highest root and shoot length and vigour index (2780 in rabi and 1908 in kharif) (Table 2). The increase in seed quality parameters may be due to the participation of micronutrients (Zn, Fe, Cu and Mn) in catalytic activity and breakdown of complex substances into simple forms like glucose, amino acids and fatty acids. These in turn were reflected on enhanced germination, elongation of root and shoot of coriander seedling (Santosh, 2012).

Foliar spray of 0.5% $FeSO_4$ recorded higher essential oil content (0.39% in rabi and 0.51% in kharif) followed by $ZnSO_4$ (Table 1). This effect of micronutrients on more essential oil percentage may be attributed to their effect on enzymes activity and metabolism improvement. The essential oil yield increased with iron and zinc applications because there was a significant increase in dry matter yield. The results on the effects of micronutrients on coriander plants agreed with the results obtained by Khalid (1996) and Mehrab (2014) who reported that trace elements such as Fe, Zn and Mn increased the vegetative growth characters and essential oil content of different plants such as anise, coriander, sweet fennel and lemon balm.

Conclusion

Coriander responded well to micronutrients. Foliar spray

Table 1. Effect of micronutrient application on seed yield and quality in coriander cv.CO_4.

Treatment (M)	Number of umbels plant^{-1}		Seed yield ha^{-1} (kg)		100 seed weight (g)		Essential oil content (%)		Protein content (%)	
	Rabi 2009	Kharif 2010	Rabi 2009	Kharif 2010	Rabi 2009	Kharif 2010	Rabi 2009	Kharif 2010	Rabi 2009	Kharif 2010
M1	17.9	9.2	459.9	446.6	1.35	1.31	0.30	0.35	10.21	11.48
M 2	27.8	10.8	603.3	566.6	1.45	1.37	0.32	0.42	11.66	13.63
M 3	29.5	11.8	609.9	583.3	1.50	1.43	0.37	0.45	12.40	14.86
M 4	33.7	11.2	579.9	483.3	1.48	1.48	0.31	0.44	11.78	13.38
M 5	33.7	13.8	623.3	599.9	1.55	1.50	0.39	0.51	12.38	14.68
M 6	20.8	8.2	556.6	406.6	1.41	1.34	0.32	0.39	11.48	13.32
M 7	22.7	10.2	509.9	476.6	1.43	1.42	0.34	0.40	11.84	13.45
M 8	21.0	10.8	479.9	443.3	1.32	1.35	0.31	0. 41	11.00	12.89
M 9	23.8	11.2	589.9	459.9	1.49	1.40	0.36	0.44	11.59	13.20
Mean	25.65	10.85	556.95	496.23	1.44	1.40	0.33	0.42	11.59	13.43
SEd	0.74	0.31	17.017	14.669	0.040	0.038	0.010	0.012	0.328	0.382
CD (P = 0.05)	1.57	0.66	36.076	31.099	0.085	0.081	0.021	0.025	0.695	0.810

Where, M1 – control (NPK); M 2 - soil application of $ZnSO_4$ @ 25 kg/ha; M 3 - foliar application of $ZnSO_4$ @ 0.5% (30 and 45 DAS); M 4 - soil application of $FeSO_4$ @ 25 kg/ha, M 5 - foliar application of $FeSO_4$ @ 0.5% (30 and 45 DAS); M 6 - soil application of $CuSO_4$ @ 25 kg/ha; M 7 - foliar application of $CuSO_4$ @ 0.5% (30 and 45 DAS); M 8 - soil application of $MnSO_4$ @ 25 kg /ha; M 9 - foliar application of $MnSO_4$ @ 0.5% (30 and 45 DAS).

Table 2. Effect of micronutrient application on resultant seed quality in coriander cv.CO_4.

Treatment (M)	Germination (%)		Root length (cm)		Shoot length (cm)		Vigour index	
	Rabi 2009	Kharif 2010	Rabi 2009	Kharif 2010	Rabi 2009	Kharif 2010	Rabi 2009	Kharif 2010
M 1	77 (61.36)	77 (61.36)	12.2	10.0	9.2	7.1	1647	1280
M 2	87 (68.87)	85 (67.22)	15.8	11.3	9.7	8.4	2218	1675
M 3	90 (71.57)	94 (76.78)	17.3	11.4	10.4	9.4	2493	1955
M 4	90 (71.57)	82 (64.90)	16.8	11.4	10.6	8.1	2466	1599
M 5	93 (75.11)	90 (71.57)	19.1	12.5	10.8	9.7	2780	1908
M 6	85 (67.22)	86 (68.03)	16.4	10.1	10.3	7.1	2269	1480
M 7	95 (77.08)	88 (69.73)	16.6	12.2	10.4	8.0	2565	1778
M 8	85 (67.22)	80 (63.44)	15.2	11.4	10.3	7.2	2167	1488
M 9	80 (63.44)	84 (66.42)	16.0	12.9	10.5	8.3	2120	1864
Mean	86 (69.27)	85 (67.71)	16.16	11.47	10.24	8.14	2304	1670
SEd	2.32	2.28	0.46	0.32	0.28	0.24	65.924	48.794
CD (P = 0.05)	4.92	4.83	0.98	0.68	0.60	0.50	139.755	103.440

Figures in parentheses indicate arc sine transformed values. Where, M1 – control (NPK); M 2 - soil application of $ZnSO_4$@ 25 kg/ha; M 3 - foliar application of $ZnSO_4$ @ 0.5% (30 and 45 DAS); M 4 - soil application of $FeSO_4$ @ 25 kg/ha, M 5 - foliar application of $FeSO_4$ @ 0.5% (30 and 45 DAS); M 6 - soil application of $CuSO_4$ @ 25 kg/ha; M 7 - foliar application of $CuSO_4$ @ 0.5% (30 and 45 DAS); M 8- soil application of $MnSO_4$ @ 25 kg/ha; M 9 - foliar application of $MnSO_4$ @ 0.5% (30 and 45 DAS).

of micronutrients was advantageous over soil application because of rapid response, effectiveness and elimination of deficiency symptoms. From the above results, it can be concluded that the foliar application of 0.5% $FeSO_4$ significantly enhanced the growth, seed yield and quality of coriander in the calcareous soils of Coimbatore.

Conflict of Interest

The authors have not declared any conflict of interest.

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REFERENCES

Abbas MK (2013). Effect of foliar fertilizer and some growth regulators on vegetative and anatomical characters of dill (*Anethum graveolens* L.). Middle-East J. Sci. Res. 13:803-811.

Abdul-Baki AA, Anderson JD (1973). Vigour determination of soybean seeds by multiple criteria. Crop Sci. 13:630-633. http://dx.doi.org/10.2135/cropsci1973.0011183X001300060013x

Ali-Khan ST, Youngs CG (1973). Variation in protein content of field peas. Can. J. Plant Sci. 53:37-41. http://dx.doi.org/10.4141/cjps73-005

Amjad A, Sajida P, Syed N, Muhammad S, Zengqiang Z, Fazli W, Mohib S, Shahida B, Abdul M (2014). Effect of foliar application of micronutrients on fruit quality of peach. Am. J. Plant Sci. 5:1258-1264. http://dx.doi.org/10.4236/ajps.2014.59138

ASTA (1968). Official Analytical Methods. 2nd Edn. American Spice Trade Association 38:9-10.

Ebrahimian E, Ahmad B (2011). Effect of iron foliar fertilization on growth, seed and oil yield of sunflower grown under different irrigation regimes. Middle-East J. Sci. Res. 9:621-627.

ISTA (2003). International Rules for Seed Testing. Zurich, Switzerland: ISTA.

Jackson ML (1973). Soil chemical analysis. Prentice Hall Indian Private Limited. New Delhi pp. 200-250.

Joynul AM, Nurul AM, Jamal HM, Nure AA, Kazi M, Faisal H (2012). Effect of micronutrients on growth and yield of onion under calcareous soil environment . Int. J. Biosci. 2:95-101.

Kalidasu G, Sarada C, Yellamanda RT (2008). Influence of micronutrients on growth and yield of coriander (*Coriandrum sativum*) in rainfed vertisols. J. Spices Arom. Crops 17:187-189.

Khalid A (1996). Effect of fertilization on the growth, yield and chemical composition of some medicinal umbelleferous plant. M. Sc. Thesis, Fac. Agric, Al-Azhar Univ. Cairo. Egypt.

Mazaheri M, Fakheri B, Piri I, Tavassoli A (2013). The effect of drought stress and micronutrient of Zn and Mn on yield and essential oil of (*Cuminum cyminum*). J. Novel Appl. Sci. 2:350-356.

Mehrab Y (2014). Effects of micronutrients foliar application on essential oils of Lemon balm (*Melissa officinalis* L.). Advan. Environ. Biol. 8:1063-1068.

Nadim MA, Awan IU, Baloch MS, Khan EA, Naveed K, Khan M A (2012). Response of wheat (*Triticum aestivum* l.) to different micronutrients and their application methods. J. Anim. Plant Sci. 22:113-119.

Naga SK, Swain SK, Sandeep VV, Raju B (2013). Effect of foliar application of micronutrients on growth parameters in tomato (*Lycopersicon esculentum* mill.). J. Agric. Food Sci.1:146-151.

Nasiri Y, Saeid Z-S, Safar N, Nosratollah N, Kazem G-G (2010). Effects of foliar application of micronutrients (Fe and Zn) on flower yield and essential oil of chamomile (*Matricaria chamomilla* L.). J. Med. Plants Res. 4(17):1733-1737.

Panse VG, Sukhatme PV (1985). Statistical methods for Agricultural workers. ICAR, Publication, New Delhi pp. 327-340.

Said-Al Ahl HAH, Mahmoud Abeer A (2010). Effect of zinc and / or iron foliar application on growth and essential oil of sweet basil (*Ocimum basilicum* L.) under salt stress. Ozean J. Appl. Sci. 3:97-111.

Salmasi SZ, Behrouznajhad S, Golezani KG (2012). Effects of foliar application of Fe and Zn on seed yield and mucilage content of psyllium at different stages of maturity. International Conference on Environment, Agriculture and Food Sciences, Phuket (Thailand).

Santosh K (2012). Effect of micronutrients on quality of fruit and seed in tomato (*Solanum lycopersicum* L.) Internat. J. Farm. Sci. 2:43-46.

Watson DJ (1952). The physiological basis of variation in yield. Advances in Agron. Academic Press Inc. New York 4:101-144.

Williams RF (1946). The physiology of plant growth with special reference to the concept of net assimilation rate. Ann. Bot. 10:41-72.

Zeidan MS, Mohamed MF, Hamouda HA (2010). Effect of foliar fertilization of Fe, Mn and Zn on wheat yield and quality in low sandy soils fertility. World J. Agric. Sci. 6:696-699.

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Full Length Research Paper

Agronomic and economic evaluation of the N and P response of bread wheat grown in the moist and humid midhighland vertisols areas of Arsi zone, Ethiopia

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Field experiment was conducted in 2012 and 2013 in three districts of Arsi zone, Oromia region, Ethiopia to evaluate the response of bread wheat cultivar "Damphe" under highland vertisols to treatments consisting of 20 factorial combinations of five N rates from urea and four P205 rates from triple super phosphate (TSP). The treatments were laid out in RCBD, replicated three times. All data were subjected to analysis of variance using SAS 9.0 Statistical Analysis Software. Treatment effects on the average grain yield (AGY) and average biological yield (ABY) were very highly significant. Number of spikes m-2, number of seeds/spike, and plant height were also significantly or very significantly affected. The main effects of fertilizer N on AGY, ABY, protein and wet gluten contents, and zeleny values of grains were also very highly significant. Leaf absorption of N increased with increased rates up to 92 kg/ha N. The N recovery efficiency (NRE) at 46 and 92 kg N/ha was 20.9% and 29.4% and the agronomic efficiency (AE) was 10.8 and 13.3 kg grain/ kg N applied, respectively. Above the 92 kg/ha N the increase in both NRE and AE declined or fell reaching 31.4 % and 12.6 kg grains/ kg N. Based on farmers capacity to invest and their inherent tendency to gradually adopt higher rates, a base recommendation of 92-46 (N- P_2O_5) kg/ha, which is equivalent to 160 kg/ha Urea + 100 kg/ha DAP is given. This rate was the treatment with highest marginal rate of return (MRR). Additional recommendation consisting of 138-69, and 115-46 (N- P_2O_5) kg/ha, equivalent to 240 kg/ha Urea + 150 kg/ha DAP and 210 kg/ha Urea + 100 kg/ha DAP is given, based on agronomic data, economic analysis, complexity in management history of different farms, and environmental considerations.

Key words: Average grain yield, agronomic data, N recovery efficiency (NRE), agronomic efficiency (AE), grain quality, marginal rate of return.

INTRODUCTION

The relatively slow growth in mean national yield for bread wheat (*Triticum aestivum* L.) from 1.46 t ha^{-1} in 2004/2005 (CSA, 2005) to 2.01 t ha^{-1} (CSA, 2011/2012) is due to several constraining factors, such as poor crop management that include the prevalence of poor weed control, exacerbated by the limited availability of herbicides in the market and its improper use when available, depleted soil fertility and a low level of fertilizer usage, particularly of N fertilizer are among the most important. Nitrogen and phosphorus deficiency is often encountered in wheat growing areas of Ethiopia, in which the severity of the problems predominate the frequently water-logged soils- highland Vertisols (Tekalign et al., 1988; Syers et al., 2001). But, the K levels, as measured by our research center for different locations of our sub centers, was found to be very high for all study areas. Since the introduction of Vertisols technologies in the 1990s, like BBM and ridge and furrow seed bed preparation methods, the very high potential of such soil for wheat productions have been well recognized by highland Vertisols areas farmers. Nonetheless, it has been underutilized due, mainly, to the very low input use of fertilizers and poor pest management strategies. Parallel to this fact researches in the development of site and crop specific fertilizer recommendations have shown modest progress until now due, possibly, to the limited resources of the country. As a consequence of this, the old bulk recommendations continued to be practiced in many areas. Despite its continued use, the importance of zone or site specific fertilizer recommendations in the country have gained the attention of many researchers and scientists since as early as the 1990s; and the progress of the works done so far indicated that increased rates of applications of N and P increased grain yields with a very strong and significant linear response (Asefa et al., 1997; Shambel et al., 1999; Minale et al., 2004; Taye et al., 2002). Notwithstanding the contributions of these authors, the scale of work done so far is very little considering the variability of soils, climate, and cropping systems. Consequently, the demand for site specific or agroecology based fertilizer recommendations have been increasing from time to time. Coupled with the demand increased implementation of improved recommendations is one of the primary means of increasing wheat yields in Ethiopia. Therefore, a fertilizer trial was conducted in 2012 and 2013 with the main objective of developing economic optimum fertilizer recommendation for bread wheat productions in three highland Vertisols dominated districts of Arsi zone. The specific objectives of the trial were to determine the effects of different rates of N and P on the yield and yield components, grain quality, fertilizer N recovery, and agronomic efficiency of bread wheat.

MATERIALS AND METHODS

Location description and soils

The experiment was conducted during the 2012 and 2013 main cropping seasons on farmers' fields in the south eastern highlands of Ethiopia, in the districts of Digelu-Tijo, Arsi Robe, and Tiyo. Arsi Robe is located from 8.4 to 8.6N and 40.1 to 40.4E, while Digelu-Tijo and Tiyo are located from 8.01 to 8.15N and 039.15 to 039.3E and from 7.77 to 8.03N and 38.94 to 39.31E, respectively, all in degree decimal. The altitudes of the locations vary from 2200 masl at Kulumsa to about 2500 masl at A. Robe and Digelu-Tijo. These three locations are located in the major Vertisols belts of the zone. The Long term average annual rainfall for Arsi Robe is 1040 mm and for Kulumsa (Tiyo district) above 840 mm. For Digelu-Tijo there are no weather station data to describe, but the amount and distributions are similar to the neighbouring districts. Therefore, its estimated average annual rainfall lie between 800 and 1000mm. Tepid to cool moist mid-highlands and Tepid to cool humid mid-highlands are the agroecological classification for the study areas (Ethio-Italian Development Cooperation, 2002). Even though the long term average annual rainfall for Arsi Robe is higher than the other location, its distributions are uneven. The soils vary from Haplic and Vertic Luvisols to Eutric Vertisols in Tiyo district to Eutric Vertisols in Digelu-Tijo and Arsi Robe (Ethio-Italian Development Coop. 2002). The average organic matter content for all locations is less than 2% and the texture vary from clayey to heavy clayey at Kulumsa (Tiyo) to generally heavy clayey at A. Robe and Digelu-Tijo. The K contents of the soils vary from above 680 kg/ha at the latter two locations to 2160 kg/ha at Kulumsa. These K values are higher than the standard, 340 kg/ha for high level of available K_2O (Sarkar and Haldar. 2005). Generally, the study areas are part of the high potential areas for wheat production in the country; and improving the fertilizer use in these areas can bring a considerable impact for increasing productions in the zone and improving the national average wheat grain yields. Selection of trial sites on farmers' fields was done in conjunction with local extension agents (Figure 1).

Treatments and experimental designs

This experiment was conducted to evaluate the response of recently released bread wheat variety Danda'e (KIRITATI/2*PBW65/2*SERI.IB) to treatments consisting of 20 factorial combinations of five N rates (that is, 0, 46, 92, 138, 184 kg/ ha) from urea and four P_20_5 rates (that is, 0, 46, 92,138 kg/ha) from triple super phosphate. The treatments were laid out in a complete factorial arrangement using RCBD replicated three times. The gross plot size of the trial was 4 × 5 m (= 20 m^2) and net plot size of 3 × 3 m (9 m^2). The fields were prepared according to the recommended practices using the traditional oxen-plow system of the ridge and furrow with a 0.7 m wide inter-furrow spacing. Seeds were sawn according to the customary Vertisols management practices of first broadcasting on the plots and then the ridge and furrows were prepared with well experienced farmers to keep the inter-furrow spacing of 0.7 m using a small ridge and furrow maker commonly called BBM. All P fertilizer and half of the N fertilizer treatments were applied at planting and the remaining N was top-dressed at booting stage. Existing recommendation of seed rate (150 kg/ha) and a herbicide called pyroxyslam, one time per season for weed control, were used.

Data collection and analysis

Data was recorded on grain yield and yield components such as: Seedling density, number of tillers per plant, spike length, kernels

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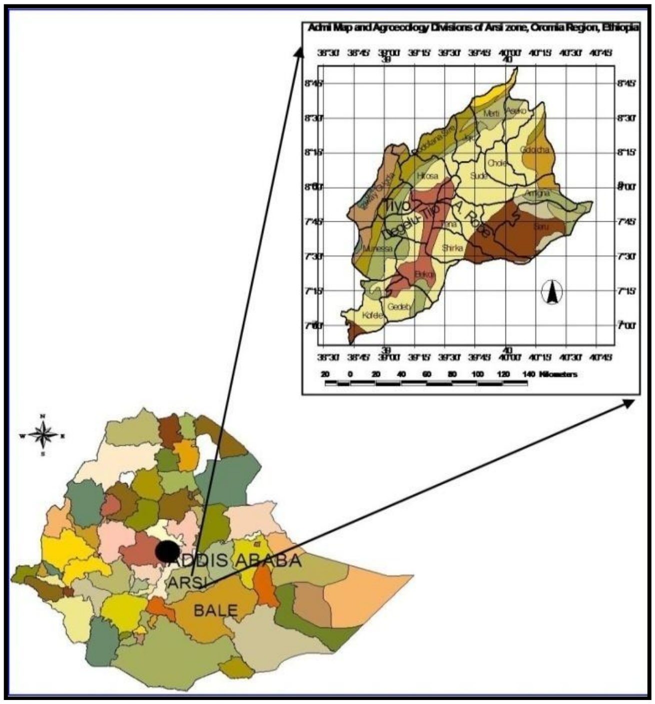

Figure 1. Geographic location description of study areas. Developed using Arsi GIS data (Ethio-Italian Development Coop. 2002) and Arc view 3.2 GIS software (ESRI, 1999).

per spike, thousand kernel weight (TKW), plant height, grain and biomass yield. Information on disease and pest incidences was also collected. Plant samples and grain samples were collected during the second cropping season from each treatment plot of two experimental sites at Digelu-Tijo district at the start of heading and after harvest, respectively.

Plant height and number of productive spikes/m^2 were determined for each treatment before harvest. Harvesting was done by hand using sickles. Hundred culm weight (100 cw) were collected from four to five points within a plot and slashed from close to the ground surface and the dry matter yield of above-ground biomass determined. Grain yield was determined from 9 m^2 net plot by hand threshing and the harvested samples weighed by using sensitive balance (capacity of 10 kg and 0.01 g sensitivity). Yield adjustments were made based on 12.5% moisture content. Above ground biomass yields were determined based on data of hundred culm weight and the harvest index (HI) calculated as the ratio of grain yield to above ground biomass yield expressed as a percentage. Thousand kernel weight (TKW) was determined by weighing 1000 grains under moisture contents adjusted to 11%.

The number of grains/spike was determined by hand counting of the number of grains of 5 spike samples and averaging them. Straw N contents were determined by micro-Kjeldahl analysis of straw sub samples (Bremner and Mulvaney, 1982) at KARC soil laboratory from the oven-dried bulk samples.

120 grain samples collected from two sites of Digelu-Tijo district for grain quality analysis. Grain Protein, starch, wet gluten, and zeleny values were determined using Near Infrared Reflectance (NIR) at Amhara Region Agricultural Research Institute (ARARI), Bahirdar, Ethiopia.

Grain N values were calculated by multiplying grain yields by the respective N content. Apparent N recovery (AR) of the grain for each treatment N was calculated as: (GNU of treatment - GNU from the control treatment) / fertilizer N applied. The GNU values were calculated from N treatments averaged over the ranges of P_2O_5 levels and replications making the degree of freedom 30. Agronomic efficiency (AE) of fertilizer N was calculated as: (grain yield of treatment -grain yield of control) / fertilizer N applied. Again the main effects of N were considered. Efficiency values calculated based on known procedures (Cassman et al., 2002; Fageria and Baligar, 2003; Doyle and Holford, 1993).

The method of partial budget analysis recommended by CIMMYT (1988) was used to evaluate the economic profitability of the various treatment options and determine the economic optimum rate. For continuous economic analysis predicted yield data was generated using the regression model developed for prediction of yield response under alternative fertilizer treatments. Data necessary for economic analysis was collected from the districts bureau of agriculture. All variable costs including land preparation, planting, weed control, and harvesting costs are estimated based on the actual field prices at the time of planting and immediately after harvest; and averaged over locations. The yield data used for economic analysis is the 2013 data, due to the better management conditions.

The costs of P_2O_5 and N fertilizer were estimated based on the cost of DAP and Urea, respectively. The Urea rates were adjusted based on the contribution of N from each treatment level of DAP to N source levels. Dominance analysis, as recommended by CIMMYT (1998), was applied to screen treatments with higher variable costs, but lower net benefits; and dominated treatments eliminated from further considerations in Marginal analysis. The minimum acceptable rate of return was taken as 100%; and treatments with lower minimum rates of return were also removed from further analysis. Finally sensitivity analysis was conducted on the selected best treatments to evaluate the effect of variability in input prices over time and space on the strength of acceptability of recommended practices under all recommendation domains.

All crop parameters data were subjected to analysis of variance using SAS 9.0 statistical software (SAS, 2002). Data were analyzed for trials combined across site and seasons. The DMRT test ($P<0.05$) was used to assess differences among treatment means. SPSS 20.0 statistical software was used to analyze the correlations between yield and yield components and the treatments, and for developing prediction models for grain and biomass yields. For graphical analysis of yield and yield components Origion 8 GUI and SPSS 20.0 softwares (Origin Lab Coop., 1991-2007; IBM, 1989-2011) were used.

RESULTS AND DISCUSSION

Grain and biomass yield responses to N and P_2O_5 rates

Grain yields and yield components of bread wheat (Danda'e/ Damphe variety) under different fertilizer rates are presented in Tables 1 to 3. Only the main effects of each fertilizer rates on the yield and yield component responses across locations and years are summarized. The main effects of N and P_2O_5 on AGY and ABY are also illustrated in Figures 2 and 3; and Figures 4 to 6 exemplify the responses of the test variety in grain quality parameters.

The average grain and biological yields (AGY and ABY) at Arsi Robe and Digelu-Tijo districts in the 2012 trial results show that the main effects of N and P are very highly significantly different, with mean grain and biological yields of 2861 and 6940, as compared to the

Table 1. The main effects of fertilizer N and P_2O_5 application rates on selected agronomic parameters of bread wheat grown on the highland Vertisols of Arsi zone in 2012 and 2013.

Sources of variation	2012 summary results of robe and Digelu-Tijo districts							2012 and 2013 summary results of Digelu-Tijo and Tiyo districts						
	PH (cm)	NSPS	SPM	AGY (Kg/ha)	ABY (Kg/ha)	HI	HLW	PH (cm)	NSPS	SPM	AGY (Kg/ha)	ABY (Kg/ha)	HI	HLW
N (Kg/ha)														
0	84.4	41.5	241	1926	5106	39.5	76.3	75.5	38.4	360	2385	6176	39.7	75.0
46	89.6	47.0	252	2554	6067	40.2	75.5	82.8	40.9	376	2852	7160	40.2	75.4
92	101.4	50.8	266	2960	7103	40.1	75.4	87.8	41.6	423	3370	8327	41.0	74.5
138	98.4	55.3	268	3368	7935	40.0	74.7	92.6	43.4	430	3916	9381	42.2	74.9
184	98.0	54.8	263	3516	8685	39.0	74.6	93.8	45.2	461	4271	10365	41.6	74.4
DMRT	**	***	*	***	***	NS	NS	***	*	***	***	***	NS	NS
P_2O_5 (Kg/ha)														
0	88.4	47.1	247	2287	5603	39.9	75.6	82.2	40.6	386	2788	6846	40.6	75.1
46	93.1	49.2	249	3004	7018	40.5	75.07	88.1	42.1	416	3511	8551	41.5	75.0
92	94.6	49.9	260	2973	7303	39.9	75.4	88.3	41.9	432	3653	9087	40.5	74.2
138	101.2	53.0	274	3205	7876	39.1	75.12	88.4	43.3	417	3637	8952	41.5	74.7
DMRT	*	*	*	***	***	NS	NS	***	NS	NS	***	***	NS	NS
N*P	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
REP	NS	NS	***	NS	*	NS	NS	*	NS	NS	NS	NS	NS	NS
N*REP	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
P_2O_5*Rep	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Control	81.3	40.4	231	1606	3910	40.7	76.4	70.3	36.5	337	**1969**	**5266**	38.47	75.02
Mean	94.4	49.8	258	2861	6940	39.8	75.3	86.7	41.96	413	3390	8341	40.98	74.8
CV	19.3	14.2	15.8	20.4	23.2	15.9	4.5	8.96	24.6	28.9	32.9	30.82	14.6	3.94

control 1606 and 3910 kg/ha, respectively. The highest AGY and ABY at Robe were 4229 and 11145 kg/ha and mean of Sagure and Tiyo 4658 and 9745 kg/ha, respectively.

The summary of 2013 results for same parameters at Digelu-Tijo and Tiyo districts of Arsi zone showed that the main effects of N and P_2O_5 were very highly significantly different, with mean grain and biological yields of 4134 and 9831 kg/ha. In contrast to the control treatment results of 2589 and 6554 kg/ha, the highest yields obtained were 5431 and 13299 kg/ha of AGY and ABY, respectively. The results of 2012 and 2013 at Arsi Robe (Table 3), although lower in the responses of economic yields, showed similar response patterns. Generally, the combined analysis of variance of data of 2012 and 2013 combined over locations also showed that the main effects of N were very highly significant on average grain yield (AGY), and average biological yield (ABY). Number of seeds per spike (NSPS) and number of spikes per meter square (SPM) were also very highly significantly affected by N than P. Treatment effects were also very highly significant for most of the parameters (Table 4).

ANOVA results did not show any significant interaction effects of N and P_2O_5 for most parameters at all locations. But tests on mean separation showed differences due to the combined effects of the two, and their interactions were also very important to influence the response levels (Figure 10). The yield component parameters that control the AGY such as: SPM and NSPS were significantly controlled by N than P. But P was crucial to increase the yield responses within the ranges of 46 to 92 kg/ha

Table 2. Main effects of N and P_2O_5 on selected agronomic parameters, 2013, Degelu-Tijo and Tiyo districts.

Sources of variation	PH (cm)	NSPS	SPM	AGY (Kg/ha)	ABY (Kg/ha)	HI
N (Kg ha^{-1})						
0	77.4	39.2	408	3025	7450	40.6
46	84.2	39.3	439	3769	9249	40.5
92	86.8	41.0	465	3973	9245	43.8
138	91.2	40.4	497	4755	11069	43.0
184	93.4	43.5	501	5111	12170	42.6
P_2O_5 (Kg ha^{-1})						
0	83.7	40.6	445	3653	8658	42.1
46	87.5	41.3	463	4206	9993	42.2
92	88.6	41.1	472	4370	10428	41.9
138	87.3	40.3	474	4312	10264	42.9
			ANOVA			
TRT	***	NS	***	***	***	NS
N*P	NS	NS	NS	NS	NS	NS
REP	NS	NS	NS	NS	NS	NS
N*REP	NS	NS	NS	NS	NS	NS
P_2O_5 * REP	NS	NS	NS	NS	NS	NS
Control	72.8	36.6	367	2589	6554	39.4
Mean	86.8	40.8	463	4134	9831	42.3
CV	7.7	18.0	12.2	22.9	23.3	13.2

Table 3. Main effects of N and P_2O_5 on selected agronomic parameters. 2012 and 2013 (Arsi Robe district).

Sources of variation	PH (cm)	SPM	NSPS	HI	AGY (Kg/ha)	ABY (Kg/ha)	HLW
N (Kg ha^{-1})							
0	79.7	295.7	39.0	35.9	1591	4397	75.4
46	87.9	298.2	42.9	37.3	2230	5525	74.9
92	91.8	339.9	45.3	37.5	2518	6382	74.6
138	95.4	351.3	48.4	38.0	2883	7174	74.2
184	95.9	361.9	48.8	38.0	3136	7914	74.2
P_2O_5 (Kg ha^{-1})							
0	86.7	316.4	42.6	38.5	2093	5266	75.1
46	91.0	325.6	45.2	37.0	2584	6444	74.5
92	90.9	344.0	44.8	37.0	2462	6317	74.7
138	92.1	335.0	46.7	36.7	2734	7014	74.3
ANOVA							
N	***	*	***	NS	***	***	NS
P	***	NS	NS	NS	***	***	NS
N*P	NS	NS	NS	NS	NS	NS	NS
REP	*	NS	NS	NS	NS	NS	NS
N*REP	NS	NS	NS	NS	NS	NS	NS
P_2O_5 * REP	NS	NS	NS	NS	NS	NS	NS
TRT	***	NS	***	NS	***	***	NS
Mean	90	329	44.8	37.3	2469	6264	74.7
Control	76.9	300	36.6	34.9	1370	3598	75.8
CV	7.6	37.8	19.5	17.5	27.0	27.7	3.9

NS stands for Non-significant (at $p < 0.05$), *** for very highly significant (at $p < 0.001$), ** for highly significant (at $p < 0.01$), and the symbol * stands for significance level (at $p < 0.05$).

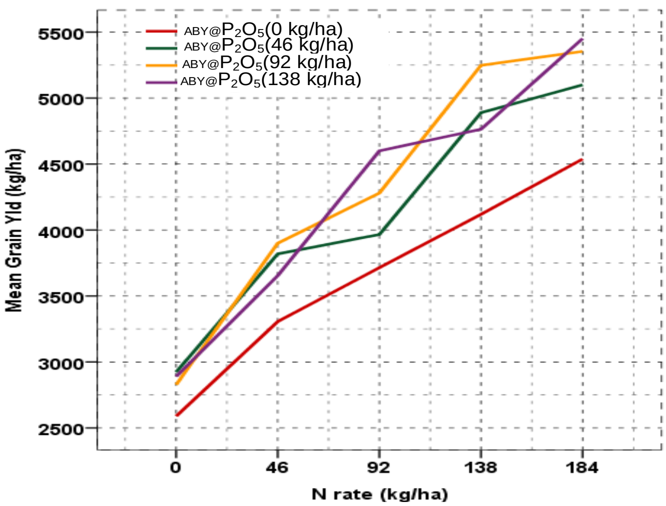

Figure 2. Response curves showing relationship between AGY responses to N levels as P_2O_5 levels (colored curves) change from 0-138 kg/ha.

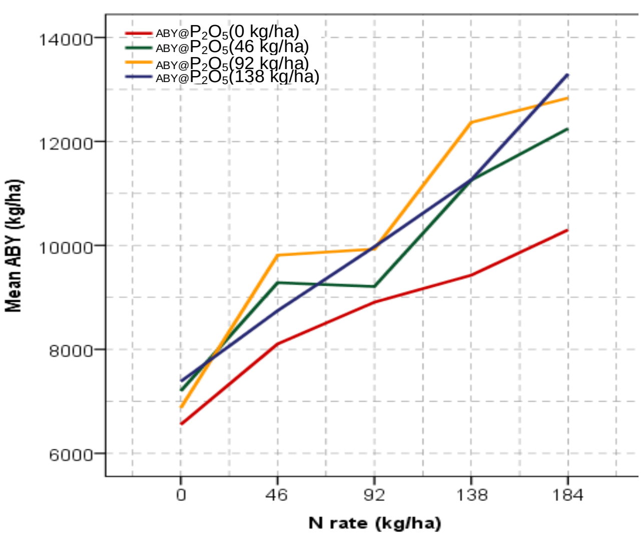

Figure 3. Response curves showing relationship between ABY responses to N levels as P_2O_5 levels (colored curves) change from 0-138 kg/ha.

P2O5 (Figures 2 and 3). Generally, the yield increments in the 2012, 2013, and mean of 2012/2013 vary from 111 to 146% and 103 to 142% for the highest treatments results of AGY and ABY, respectively, as contrasted to the control treatment results.

The relationship between AGY and different rates of N and P can be expressed using the following second degree polynomial equation, with R^2=0.97 for AGY. The predicted average grain yield is expressed by:

$$PAGY = c + aN + bP_2O_5 - dN^2 - e(P_2O_5)^2 + f(N * P_2O_5)$$

Where: PAGY is predicted average grain yield, c is a constant with a value of 2667 kg/ha, a, b, d, e, and f are coefficients with values of 12.84, 12.7, 0.015, 0.07, and 0.019, respectively. The parameters PAGY, N, P_2O_5 are all in kg/ha. Grain yield responses of the test variety to N and P_2O_5 combinations, not included in the treatments, were predicted using the equations developed for AGY and the values applied during economic analysis. The model can provide very good input and yield predictions for field conditions that can be well managed. The results obtained so far are also in agreement with the works done on bread and durum wheat (Asefa et al., 1997; Shambel et al., 1999; Minale et al., 2004; Taye et al., 2002).

Effect of N and P_2O_5 on Grain quality

Increased rates of N had significant effect on grain protein and wet gluten contents, and zeleny values. The average protein contents obtained from highest to lowest were 13.39, 12.50, 12.0, 11.02, 10.76% from applications of 184, 138, 92, 46, 0 kg/ha N, respectively. The wet gluten contents from highest to lowest: 30.71, 29.64, 27.52, 23.73, and 23.59% were obtained from applications of 184, 138, 92, 46, and 0 kg/ha, respectively. Similarly, Nitrogen had had very high significant effect on the Zeleny values, but no significant effect on starch content. Generally, the main effects of N, when contrasted with the control treatment, increased the grain protein, wet gluten and zeleny values by 25, 34 and 44%, respectively, at the highest rate of N. The result is clearly indicative of the fact that Nitrogen is the main determining factor to improve the grain quality of bread wheat (Figure 4).

The effect of P nutrition on grain quality was insignificant (Figure 5). Protein and starch contents were not significantly affected by increasing rates of P, but Zeleny values negatively affected. The wet gluten content slightly raised at the 92 kg/ ha P_2O_5 rates.

Leaf analysis

Leaf samples were collected from two trial sites on farmers' fields for analysis of N absorption by the plant. The results of the analysis indicated that absorption of N was highly significantly affected by increasing rates at (p>0.0016). The mean absorption was 2.6%. The highest rates of absorption was 2.9% from plots that received 138 kg/ha N, the second highest was 2.82% from plots that received 92 kg/ha N. The third highest was 2.58% from plots that received the highest N rates (184 kg/ha). The lowest absorption recorded was from plot that received no N.

Contrary to the effect of the highest rates of N on the grain protein or N contents, leaf absorption was intermediate to the highest rates. This may be due to, possibly, higher associated losses. The effect of

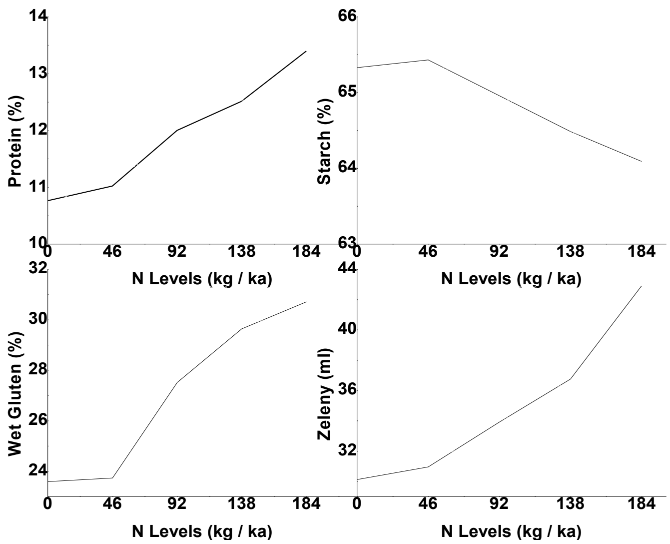

Figure 4. Relationship of Grain quality parameters with fertilizer N nutrition averaged over 2 locations.

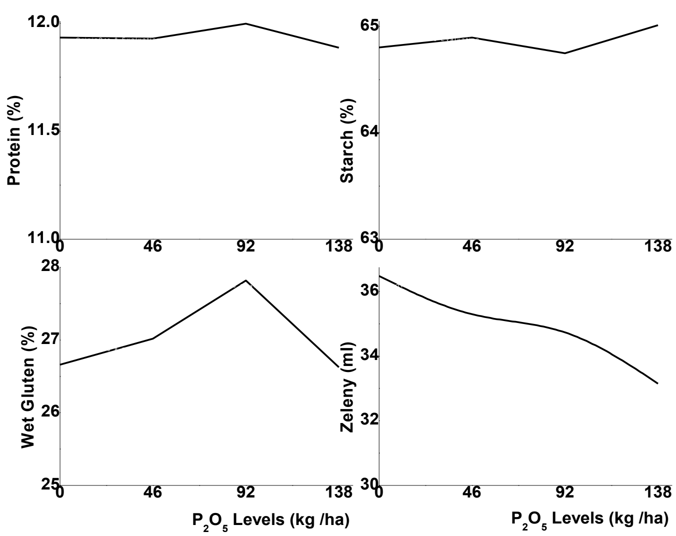

Figure 5. Relationship of Grain quality parameters with P nutrition averaged over 2 locations.

different rates of P on the leaf absorption was insignificant; and no interaction effect of N and P was observed.

Fertilizer N recovery and agronomic efficiency

Fertilizer N uptake and agronomic efficiency was calculated based on data from quality analysis. The NRE steadily increased with N rates up to 92 kg/ ha, remained constant between 92 and 138 kg/ha N, and slowly rises after that. Similarly, the agronomic efficiency of N

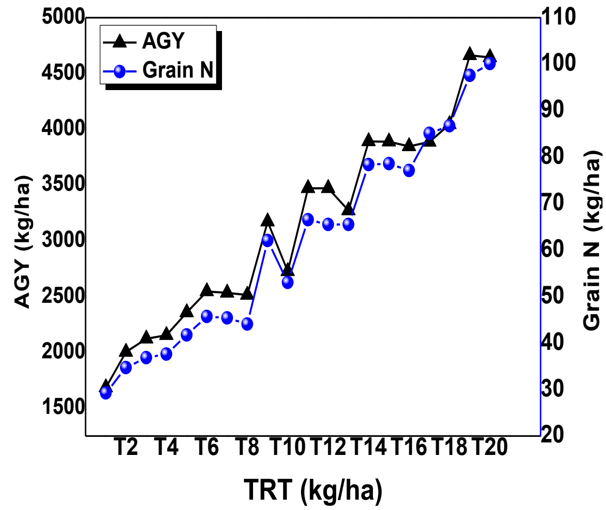

Figure 6. Relationship between AGY and grain N with changes in fertilizer N and P treatment combinations.

increases up to 92 kg/ha N, and declines after that. At 46 and 92 kg N/ha the NRE was 20.9 and 29.4% and the AE was 10.8 and 13.3 kg grain/ kg N applied, respectively. The highest NRE was 31.4% at the highest N. On the other hand the AE at the rates of 138 to 184 was 12.6 kg grain/ kg of N applied.

Generally, the highest response values were obtained at 92 kg N/ha (Figure 7). The results obtained so far are in agreement with the works done on bread and durum wheat (Tilahun et al., 1996)

Economic analysis

Every shift in investment from the lower selected treatments to higher resulted to more than 100% return (Figure 8). The marginal rate of return (MRR) generally varied from 1.14 to 4.19. The highest MRR was obtained from applications of 92-46 kg/ha N- P_2O_5. Further increases in fertilizer use, particularly of nutrient N, still held positive yield rewards. The values in the vertical axis (Figure 9) show the return in birr for every 1 birr invested on fertilizers. The highest MRR (4.19) was obtained from application of 2.61 units of fertilizer, which is equal to 160 kg/ha Urea + 100 kg/ha DAP. The MRR generally declines with increased applications of Fertilizer N (Figure 9).

Sensitivity analysis was made based on data used in the MRR analysis and with treatment results above 100% minimum rate of return, except for the control. The if-analysis was done with the assumption of an average of 30% rises in all variable costs within 3 years time, keeping the prices of the produce constant. This is one scenario in the analysis. The second scenario can consider varying both the TVC and price of produce. But, the analysis using the first scenario resulted in more than

Table 4. Main effects of N and P_2O_5 on selected agronomic parameters, combined over seasons and locations.

Sources of variation	PH (cm)	SPM	NSPS	HI	ABY (Kg/ha)	AGY (Kg/ha)	HLW
N (Kg ha^{-1})							
0	78.9	333	39.1	37.5	5415	2076	75.1
46	86.9	336	41.9	38.7	6518	2640	74.8
92	89.9	386	43.8	39.8	7414	3053	74.7
138	94.0	398	46.1	39.1	8384	3465	74.3
184	95.0	412	46.6	39.7	9461	3853	74.2
P_2O_5 (Kg ha^{-1})							
0	85.7	358	42.0	39.7	6360	2596	74.9
46	89.8	371	43.4	38.7	7600	3125	74.7
92	90.0	378	43.9	38.8	7839	3168	74.4
138	90.6	391	44.7	38.6	8006	3223	74.4
ANOVA							
N	***	***	***	NS	***	***	NS
P	***	NS	NS	NS	***	***	NS
N*P	NS	NS	NS	NS	NS	NS	NS
REP	NS	NS	NS	NS	NS	NS	NS
N*REP	NS	NS	NS	NS	NS	NS	NS
P_2O_5 * REP	NS	NS	NS	NS	NS	NS	NS
TRT	***	NS	***	NS	***	***	NS
Mean	89.0	374	43.5	39.0	7440	3023	74.6
Control	75.5	323	37.3	37.9	4583	1776	75.4
CV	7.6	32.5	19.4	16.8	33.8	36.8	3.5

The level of significance at p<0.05 is designated by *, p<0.01 by **, and p<0.001 by ***.

100% minimum rate of return for the 13 selected treatments. So there was no need to go to the second scenario, as it is obvious that the second scenario can result in minimum rate of return of values greater than the first.

The additional benefits that could be obtained from the production process were straw yields, soil quality, and grain quality improvements. The additional economic advantages that could be obtained from such additional benefits were not considered in the economic analysis due to the difficulties posed in the estimation of the market values of straw, the lack of grain quality standards to set premium prices, the complexity in using the methodology for measuring the economic values associated with changes in soil qualities.

CONCLUSIONS AND RECOMMENDATIONS

The response of bread wheat to increased rates of both fertilizer N and P_2O_5 is very high. It is more responsive to N than P. The two year results clearly showed that the ranges of P_2O_5 necessarily be used to increase yield should lie between 46 and 92. The response to N levels increased up to the maximum applied rate, 184 kg/ha. But the increase in NRE with increases in applied N declined after the 92 kg/ha N. This result is a very good indication of the fact that N losses increase with increased applications of N.

From analysis of agronomic data the highest yields were obtained through applying the highest treatment of N and P. On the other hand, the results of economic analysis showed that the highest MRR was obtained from application of 92- 46 kg/ha N- P_2O_5.

Increased fertilizer N greatly affected the grain qualities of bread wheat, especially of grain protein and wet gluten contents and zeleny values. However, the effect of fertilizer P nutrition on grain protein, wet gluten, and zeleny values is insignificant. The result is clearly indicative of the fact that Nitrogen is the main determining factor for improving the grain quality of bread wheat.

Poor fertilizer use is one of the major bottlenecks for improving wheat yields in almost all highland Vertisols areas of Ethiopia. Farmers generally use below the optimal rates of fertilizers necessary to improve yields. Even those farmers considered to be good users took for granted DAP fertilizer as the most important input to sustain or improve productions. However, the results of this experiment and many previously done works proved otherwise. The use of chemical fertilizer has to be increased above the currently practiced rates, especially of nutrient N.

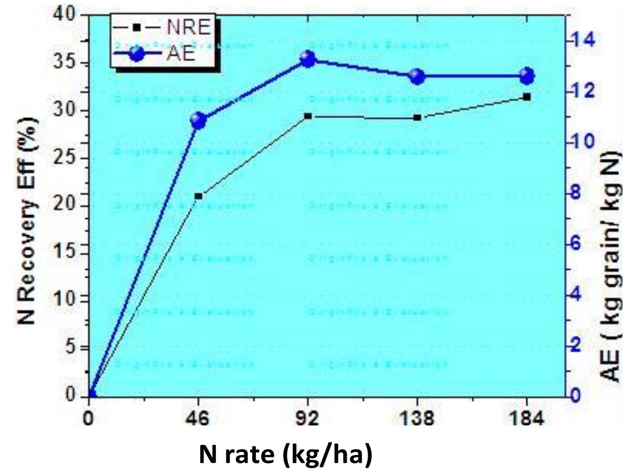

Figure 7. Curve showing the relationship between fertilizer recovery efficiency (NRE, left y-axis) and AE (right y-axis).

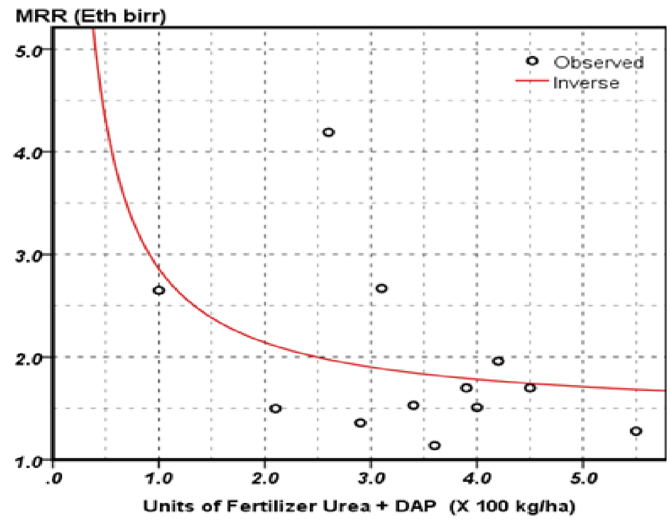

Figure 9. Trend curve showing the inverse relationship of MRR (net return for every one birr invested) with units of fertilizer applied increase.

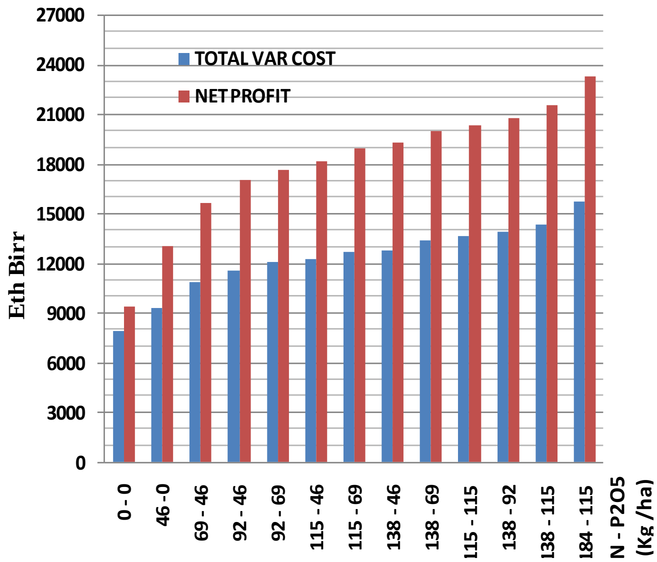

Figure 8. Bar graph showing the relationship between total variable costs and net benefits as per treatments selected based on dominance analysis.

Based on farmers capacity to invest, their tendency to gradually adopt higher rates, and the MRR values, the 92-46 (N- P_2O_5) kg/ha, equivalent to 160 kg/ha Urea + 100 kg/ha DAP is recommended. It would be better to advice poor farmers to start with this lowest level recommendation. With the increasing benefits they experience they can progressively develop to higher levels. Based on the need to attain the long term high yield goals set by planners, the 138-69 (N-P_2O_5) kg/ha, equivalent to 240 kg/ha Urea + 150 kg/ha DAP is recommended. For some lead farmers and for progressive use by resource poor farmers providing an intermediate recommendation of 115-46 (N- P_2O_5) kg/ha, equivalent to 210 kg/ha Urea + 100 kg/ha DAP is necessarily given. However, care need be taken when using the highest recommendation. It should specifically applied to farms with a very poor management history (very low or no fertilizer use, no crop rotations and residue management).

Sensitivity analysis showed that the improved recommendation would remain highly profitable for years to come; and that the validity of the recommendations made could continue over the course of time across the recommendation domains. The results of the trial can be extrapolated to other Vertisols areas of similar agroecology,

Increased N fertilizer use, particularly above the 92 kg/ha rate, should consider increased application frequency to minimize losses. The current practice or teaching is to split in to two; and this practice does not consider the changes in crops response and N recovery efficiency at very low and very high rates.

The issue of fertilizer use efficiency (FUE) that include timing and frequency at very low and very high rates, under major agroecological conditions, therefore, need be considered as one research agenda for further work.

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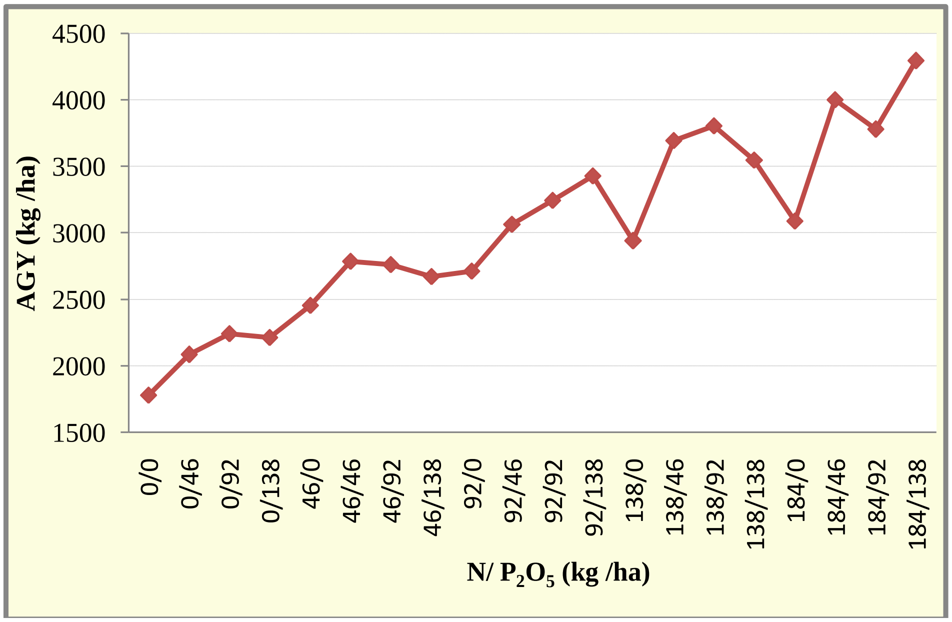

Figure 10. General response curve of bread wheat to fertilizer treatments averaged over locations and years.

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Conflict of Interest

The authors have not declared any conflict of interest.

REFERENCES

Asefa T, Tanner DG, Kefyalew G, Amanuel G (1997). Grain yield of wheat as affected by cropping sequence and fertilizer application in southeastern Ethiopia. Afr. Crop Sci. J. 5:147-159.

Bremner JM, Mulvaney CS (1982). Total nitrogen, in A.L. Page, R.H. Miller, and D.R. Kenney, Eds. Method of Soil Analysis, Part 2, Agronomy Monograph No. 9, Am. Soc. Agron. Madison, WI, pp. 595-624.

Cassman KG, Doberman A, Walters DT (2002). Agroecosystems, nitrogen use efficiency, and nitrogen management. Ambio 31:132-140. PMid:12078002

CIMMYT (1988). From agronomic data to farmer recommendations: An Economics Training Manual. Completely revised edition. Mexico, D.F.

CSA (2005). Report on Area and Production of Major Crops (Private Peasant Holdings, Meher Season). Statistical Bulletin. Volume I. May. 2005. Addis Ababa.

CSA (2011). Report on area and production of major crops (private peasant holdings, Meher season). Statistical Bulletin. Volume I. April 2011, Addis Ababa.

Doyle AD, Holford ICR (1993). The uptake of nitrogen by wheat, its agronomic efficiency and their relationship to soil and fertilizer nitrogen. Aust. J. Agric. Res. 44:1245-1258. http://dx.doi.org/10.1071/AR9931245

ESRI (Environmental Systems Research Institute) (1999). ESRI (Environmental Systems Research Institute) (1991-1999). Arc View GIS 3.2. Software Program. USA.

Ethio-Italian Developemtn Cooperation (2002). Atlas of Arsi zone. Arsi-Bale Rural Development Project. Arsi zone Planning and Economic Developemnt Office. Regional State of Oromia. GIS sub unit.

Fageria NK, Baligar VC (2003). Methodology for evaluation of lowland rice genotypes for nitrogen use efficiency. J. Plant Nutr. 26:1315-1333. http://dx.doi.org/10.1081/PLN-120020373

IBM Corporation (2011). IBM Corporation (1989-2011). SPSS Statistical Software. Version P. 20.

Minale L, Alemayehu A, Tilahun T, Abreham M (2004). Response of Bread Wheat to Nitrogen and Phosphorous Fertilizers at Different Agroecologies of Northwestern Ethiopia. In Proceedings of the 12th Regional Wheat Workshop for Eastern, Central and Southern Africa. Nakuru, Kenya. PMid:15144491

Origin Lab Coorporation (2007). Origin Lab Coorporation (1991-2007). Origin 8 Graphical User Interface (GIU). Northampton. MA 01060 USA.

Sarkar D, Haldar A (2005). Physical and Chemical Methods in Soils Analysis. Fundamental Concepts of Analytical Chemistry and Instrumental Techniques. ISBN. New Age International Limited. New Delhi.

SAS Institute (2002). The Statistical Analysis Software System for Windows. Version 9.00. TS Level 00M0. SAS Institute Inc., Cary NC. USA.

Shambel M, kefyalew G, Workiye T, Amanuel G, Mekonnen K (1999). On-farm N & P fertilizer trial in Bread wheat on vertisols in South eastern Ethiopia. Agronomy and Crop Physiology progress report. Kulumsa Agricultural Research Center. EIAR. Ethiopia.

Tekalign M, Haque I, Kamara GS (1988). Phosphorus status of some Ethiopian Highland Vertisols. In Proceeding of Management of Vertisols in the Sub-Saharan Africa. International Livestock Center for Africa. Addis Ababa. Ethiopia.

Syers JK, Craswell ET, Nyamudeza P (2001). Research Needs and Opportunities for Farming Vertisols Sustainably. In ed. Syers JK, Penning FW, Nyamudeza P (2001). The Sustainable Management of Vertisols. CABI Publishing. New York. USA.

Taye B, Yesuf A, Sahlemedhin S, Amanuel G, Mohammed H, Tanner DG, Tesfaye T (2002). Optimizing Fertilizer Use in Ethiopia. Correlation of Soil Analysis with Fertilizer Response in Hetosa Wereda, Arsi Zone. EARO/SG-2000 Collaborative Research.

Tilahun G, Tanner DG, Tekalign M, Getinet G (1996). Response of rainfed bread and durum wheat to source, level and timing of nitrogen fertilizer on two Ethiopian Vertisols: II. N uptake, recovery and efficiency. Kluwer Academic Publishers. Printed in the Netherlands.

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Full Length Research Paper

Urban farmer practices in soil fertility and water management and the influence of gender in Harare and Chitungwiza, Zimbabwe

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Poor soil fertility and increased frequency of mid-season droughts have made it difficult for urban farmers to get sustainable crop yields against a background of unemployment and reliance on urban agriculture for livelihoods in Harare and Chitungwiza. It is important to know soil fertility and water management practices used by urban farmers so that their performance can be evaluated and gender influence on their use assessed. The objectives of this study were (i) to identify soil fertility and water management practices used by urban farmers and their effect on maize yields and (ii) to determine the influence of gender on their use. Results showed a dominance of women (62.4%) over men (37.6%) in carrying out farming activities. Farmers used a combination of either poultry manure, sewage sludge or cattle manure with mineral fertilizers and attained an average maize grain yield of 1.5 t/ha. More women used organic fertilizers than men, but they applied lower rates leading to lower yields. Quantity of mineral fertilizer and sewage sludge used was significantly correlated with gender. More women than men used ridges and furrows, raised beds and mulching as water management practices. Development programs targeted for these farmers should consider gender in their design to ensure sustainability.

Key words: Gender, manure, soil fertility, urban agriculture, water management.

INTRODUCTION

In most developing countries, poverty, food insecurity and malnutrition have become critical urban problems as more people move to urban areas (WOGAN, 2009). To solve this problem, food production in and around cities is an important strategy to meet household food self sufficiency particularly in major cities in sub-Saharan Africa. Drescher (1994) reported that close to 40% of households in Lusaka, Zambia and 29% in Nairobi, Kenya relied on the urban environment to grow food for consumption and sale. High rural-urban migration after independence coupled with decline in income since 1990 has contributed to the increase in urban agriculture (UA) in Zimbabwe (Mbiba 1995). Bowyer-Boyer and Drakakis-Smith (1996) reported that 60% of the food consumed by

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low-income groups in Harare was self produced through urban agriculture. About 40% of the farmers produced enough food to cover half a year's consumption (Toriro, 2007). By the year 2000, the land under cultivation in Harare was 36% of open space (10,000 ha) (Mbiba, 2000) on which crop production was practiced with maize grown during the rainy season (November-April) and vegetables grown during the dry season (May-September). When practiced effectively, UA can contribute significantly to socio-economic development by providing income and improved food and nutrition security.

Farmers in most urban communities in Zimbabwe have experienced low yields due to several reasons. One of the reasons is poor soil fertility as a result of inappropriate practices such as burning crop stover and other trash before tillage. Burning crop residues results in reduction in soil organic carbon thereby contributing to increased nutrient loss through erosion. As in most parts of Zimbabwe, the majority of the soils are derived from granitic rocks with inherent deficiency in key essential nutrients (Nyamangara et al., 2000). This implies that nutrients should be added in the form of organic and/or mineral fertilizers in order to maintain soil nutrient supply potential. However, most of the urban farmers are economically marginalised hence cannot afford to buy the needed nutrient resources to improve crop yields. An increase in rainfall unreliability and mid-season droughts has also contributed to low crop yields especially on sandy soils. Limited access to irrigation (except for plots along streams where wastewater is used for vegetable production) (Mapanda et al., 2005) has also negatively affected crop growth. It is therefore necessary to find out how urban farmers are trying to manage the environmental conditions of limiting water and nutrients for crop production in order to optimize productivity.

Gender roles in soil fertility and water management have also become important in UA as women and men have different but specific contributions in soil fertility and soil water management (Mbiba, 1995; Mudimu, 1996). Gender as an analytical category is meant to capture a complex set of social processes; involves the examination of men's and women's roles, responsibilities, and social status in relation to cultural perceptions of masculinity and femininity (Overholt, 1991; FAO, 2002). Gender analysis therefore allows for the disintergration of data on UA and to explore why certain processes and structures generate different opportunities and constraints for different people (Hovorka, 2005). It is therefore important to analyse how gendered the responsibilities in soil fertility and water management in UA are so as to enable a more focussed provision of extension services, training and financial support to allow for efficient and sustainable crop production. The objectives of this study were to identify farmer soil fertility and water management practices used to grow crops in Harare and Chitungwiza and to determine the influence of gender on the implementation of such practices.

Study area

The study was conducted in Harare (17°46'S and 30°54'E) and Chitungwiza (18°00'S and 31°00'E) (Figure 1) in Zimbabwe. Harare and Chitungwiza are the major cities in Zimbabwe (en.wikipedia.org/ 2010) and are situated on a watershed plateau. These cities have been experiencing exponential population growth of 5 to 7% per year due to internal displacement caused by drought and political and economic instability (Kisner, 2008). The majority of soils in the northern part of Harare are red clays classified as chromic luvisols (FAO/UNESCO, 1998) derived from dolerite and are relatively fertile. Chitungwiza is covered by coarse grained sandy loam soils derived from granitic parent material, which are relatively less fertile and are classified as ferrallitic cambisols (FAO/UNESCO, 1998). These two represent the dominant soil types used for agriculture in the two cities. The main crops grown include maize (*Zea mays* L), beans (*Phaseolus vulgaris*) (Toriro, 2009), sweet potatoes (*Ipomea batatas*), groundnut (*Arachis hypogaea* L), and vegetables such as mustard rape (*Brassica juncea*), tomato (*Lycopersicon esculentum*) and giant rape (*Brassica napus*). The majority of the crops are rain-fed and therefore grown between November and March (rain season) except for vegetables which are also grown during the dry season using wastewater for irrigation (Tandi et al., 2004; Mapanda et al., 2005).

MATERIALS AND METHODS

A survey was conducted over a period of four weeks (July to August, 2010) where structured questionnaires were administered to 205 farmers (137 in Chitungwiza and 68 in Harare to account for differences in soil type).The farmers who were interviewed constituted 30% of farmers in the extension workers' records and were selected using the random number method. Key questions covered aspects on crop production systems (soil fertility management practices such as types and rates of fertilizers used and water management technologies) and gender responsibilities in soil fertility and water management activities. Key informant interviews using semi-structured questionnaires were conducted with 4 local extension workers and local authorities (District administrator and 4 ward councillors) and farmer group chairpersons. A participatory workshop was also held with local authorities, extension workers and farmer representatives. The aim of both the key informant interviews and workshop was to obtain general information on issues that affected urban agriculture such as availability and access to land, soil fertility management practices, water management technologies, number of households engaged in cropping, crop management and land degradation challenges.

Characterization of organic manures used was done to determine total nitrogen (N) (so as to calculate N application rates related to recommended rates), total phosphorus (P) and pH. Poultry manure and cattle manure samples were obtained locally from Dutch Poultry Farm and Nyarungu dairy farm respectively and sewage sludge from Zengeza sewage treatment works, which lie about 20 km south of Harare. These are the most common sources of organic amendments used by the urban farmers. The fertilizers were air-dried and ground to pass through a 2 mm sieve prior to analysis. Total N in manure was determined by the semi-micro-

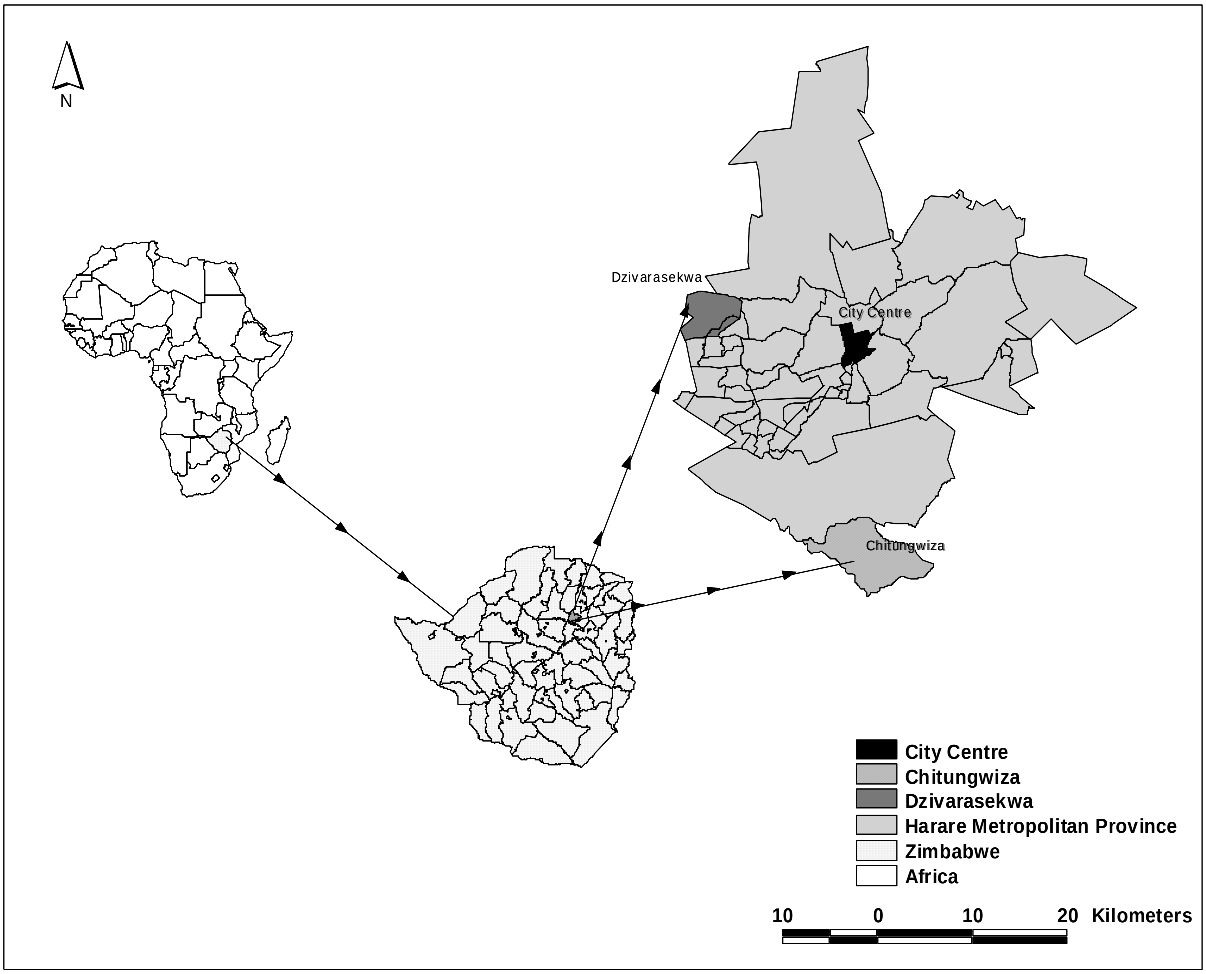

Figure 1. The study sites; Harare and Chitungwiza in Zimbabwe.

Kjeldhal method (Okalebo et al., 2002). Total C was estimated from organic matter loss by weight after overnight slow ignition in a muffle furnace at 550°C. Manure pH was determined in 1 to 5 manure to distilled water suspension as described by Okalebo et al. (2002).

Data analyses

The responses from the questionnaires were post coded and analysed using the Statistical Package for Social Sciences (SPSS version 16). A double-entry system was used to minimize errors, data cleaning was done and inconsistencies rectified by referring back to the respective questionnaires. Descriptive statistics such as means, frequencies and cross-tabulation analysis (to compare variables across gender groups) were done. Independent t-tests were done so as to compare means between males and females.

RESULTS

Manure characterization

Initial composition of domestic sewage sludge, poultry and cattle manure showed that sewage sludge had the highest total N content followed by poultry manure then cattle manure. Carbon to nitrogen ratio (C-to-N) was in the order cattle manure > sewage sludge > poultry manure (Table 1) implying that cattle manure had the poorest quality. Sewage sludge was acidic and this may negatively affect microbial activity and nutrient availability.

General characterization of gender roles

Most farming activities such as land preparation, planting and fertilizer application were done mostly by women (Table 2) who dominated urban agriculture in Harare and Chitungwiza (62.4%) over men (37.6%). Over 90% of female farmers were not formally employed as compared to 25% of their male counterparts and hence women carried out most of the farming activities while male farmers were at work. However the guarding of fields, which was risky and also occurred at night, was done mostly by men (23% male compared to 4% female) as

Table 1. Selected properties of organic manures used.

Organic manure	pH	Total N %	Organic C %	C-to-N
Poultry manure	7.2	2.26	41.22	8.56
Cattle manure	7.7	1.26	15.27	12.12
Sewage sludge	4.8	3.26	27.99	8.59

Table 2. Gendered labour responsibilities in Harare and Chitungwiza urban agriculture.

	Activity							
% responsible	Land preparation	Planting	Fertiliser application	Weeding	Irrigating	Pest control	Guarding	Harvesting
Men	33.7	16.1	12.7	11.8	6.8	16.6	22.9	10
Women	43.4	46.3	47.8	45.6	6.3	5.9	3.9	40
Both	22	37.1	39	39.7	3.9	4.4	5.4	46
Neither	1	0.5	0.5	2.9	82.9	73.2	67.8	2.9

well as use of plant protection chemicals to control pests and diseases (17% male compared to 6% female).

Tillage and land preparation practices

The majority of farmers in Harare and Chitungwiza (77%) practiced minimum tillage using hand hoes. This method tills the soil to about 10 cm after removal of all the crop residues. Of the 24% farmers that used conventional tillage (using tractors or ox-drawn ploughs), 77% were men.

The tillage services were hired and therefore could only be afforded by resource-endowed farmers who were mainly male farmers in formal employment.

Soil fertility practices

At the two study sites, farmers used a combination of poultry manure, domestic sewage sludge, cattle manure and mineral fertilizers at rates below the recommended despite most of them cultivating small pieces of land (average 0.84 ha). In Chitungwiza (sandy soils), men generally applied on average 19.5 kg N/ha and women applied 15.5 kg N/ha from a combination of organic manure (basal) and mineral fertilizers (top dressing). The N rate was only 52.2% of recommended rate (67 kg N/ha) for low agriculture potential maize (FAO, 2006). In Harare (clay soils), the farmers used mineral fertilizers only. Farmers applied these amendments by broadcasting or placing in planting statitons. Low application rates of fertilizer resources resulted in low maize grain yields of 1.5 t/ha even when mineral and organic sources of fertilizers were applied in combination. Maize grain yield averaged 1.1 t/ha when mineral fertilizer only was applied (Figure 2).

This study found that female farmers applied significantly higher amount of sewage sludge (*t(203)=2.00 p=0.047*). Men on the other hand, applied significantly higher amount of mineral fertilizers (Basal N, P, *K t(203) = 2.034, p=0.043*; Top dressing *t(203)=1.997, p=0.05)*. Across sites, men applied an average of 110 kg/ha of basal mineral fertilizer (N:P:K, 7:6:7) per season to maize compared to women who applied 86 kg/ha. However, both rates were lower than recommended rates (200 kg/ha) for low agricultural production potential areas (FAO, 2006).

Although more women than men used animal manure as organic amendments in Chitungwiza (sandy soils), women were associated with lower application rates except for domestic sewage sludge (Figure 3). However, the application rates of animal manures were very low in all cases (< 1 t/ha) compared to the recommended 10 t/ha if cattle manure is applied as the sole basal fertilizer for maize (Nhamo et al., 2004). Despite higher domestic sewage sludge application rate by women, their mean maize yield was lower than that obtained by men (Figure 3).

Water management practices

Farmers in the two study sites used at least one practice for managing soil water (Table 3). The most common practices were pre-plant ridges and furrows which were constructed in such a manner that maize was planted on the ridge. After harvesting the stover is placed in the furrows and covered with soil from the old ridge thereby creating a new ridge for the next season. Decomposition of the stover improves soil fertility but can result in intense soil N immobilisation with negative effects on yield if inadequate mineral N is applied at planting. Construction of raised beds (1 - 3 m wide) to drain excess

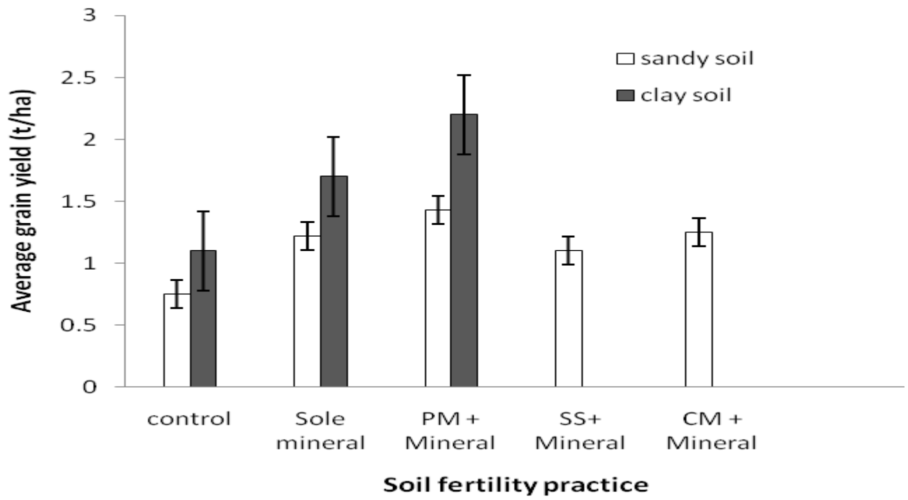

Figure 2. Maize grain yield attained from different fertilizer amendments on sandy (Harare) and clay soils (Chitungwiza) (Error bars represent standard error of means).

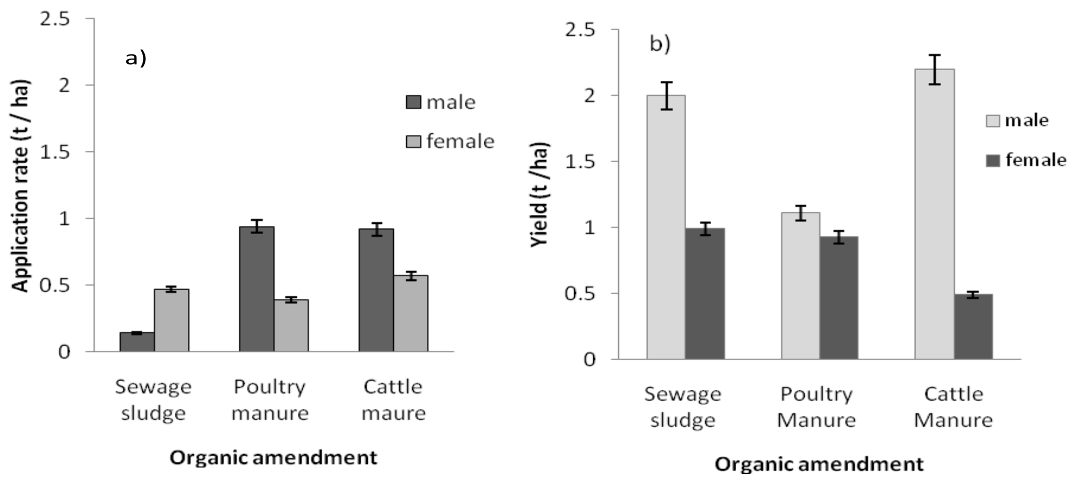

Figure 3. Manure application rates (a) by gender and (b) and maize grain yield attained in Harare and Chitungwiza (Error bars represent standard error of means).

water, was also done in fields located in wetlands. Mulching with grass, maize stover, banana leaves and sugarcane residues to conserve moisture was one of the water management practices used for both vegetable and maize production. The least used moisture conservation technologies were pot holing and winter ploughing.

In Chitungwiza (sandy soils), use of water management practices significantly improved maize yield and the latter was higher for men than women farmers. In Harare (clay soils), however, use of water management practices depressed maize yield for both male and female farmers (Figure 4). Most of the production (80%) was rain fed except where waste water and groundwater was used for irrigation of green maize and vegetables. Of the farmers that practiced irrigation, 53% were men.

DISCUSSION

Farmers in Harare and Chitungwiza have resorted to the use of different soil organic amendments to counter the effect of poor soil fertility and improve their crop yields. The use of animal manure and domestic sewage sludge was common because these amendments were readily available to the farmers and in some cases are free. Animal manures and domestic sewage sludge are good examples of organic amendments with fertilizer value that improve plant growth directly through nutrients which are slowly released through mineralization and indirectly by improving the physical and biological properties of the soil, such as water retention, aeration and microbial activity and diversity. Domestic sewage sludge is

Table 3. Water management practices (by gender) used by farmers in Harare and Chitungwiza.

Water management practices	Farmers using practice	Female farmers (%)	Male farmers (%)
Ridges and furrows	93	71	29
Raised beds	52	58	42
Mulching	61	51	49
winter ploughing	19	74	26
Pot holing	8	63	37

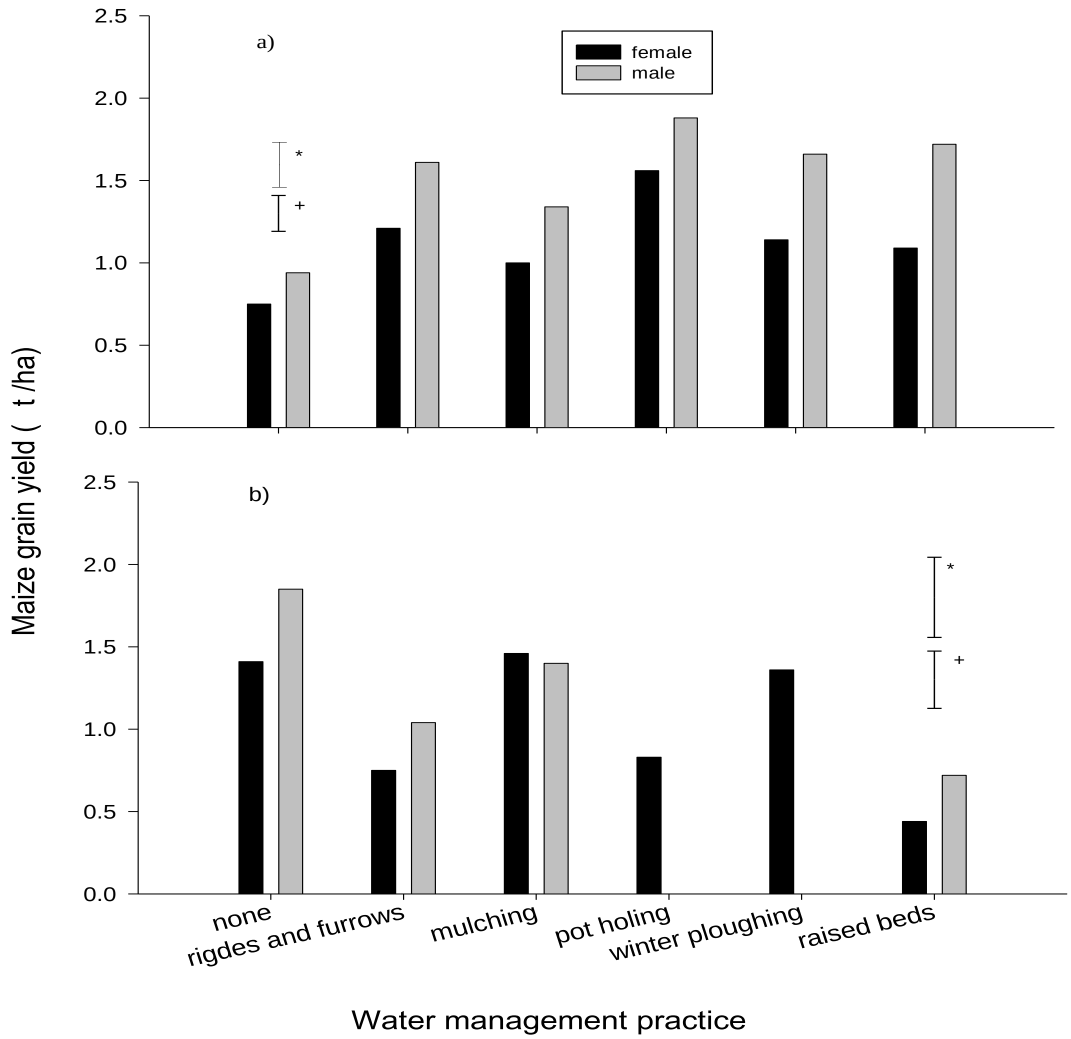

Figure 4. Maize grain yield and water management practices by gender for (a) Chitungwiza (sandy soils) and (b) Harare (clay soils) (Error bars represent standard error of means).

inherently deficient in potassium (Nyamangara and Mzezewa, 1996). However the application rates for the organic resources was too low (Figure 3) to significantly increase crop productivity. Only a fraction of the nutrients contained in organic matter are mineralised in the first year, the balance is released in the second and third years. Therefore combined application of organic and inorganic nutrient sources, in adequate amounts, is a viable strategy to enable high productivity on the small pieces of land cultivated by the majority of the farmers. Organic amendments can ensure increase in soil microbial biomass C and N due to labile organic compounds in them which provide energy sources for soil microbes while the mineral fertilizer ensures that the nutrients are supplied in forms that are soluble and readily available for plant uptake (Chen, 2008). The acidifying effects of the inorganic fertilizer are mitigated by the organic fertilizers which release bases into the soil resulting in better soil health. Organic fertilizers are important in sandy soils which are inherently infertile and weakly buffered against development of acidic conditions and degrade easily when continuously cultivated without organic inputs.

However, the use of domestic sewage sludge is of concern because of potential hazards such as the presence of pathogenic organisms (e.g. bacteria, protozoa and viruses), excess salts and the presence of heavy metals (e.g. copper, lead, and cadmium) (Mapanda et al., 2005). Salts destroy soil structure and can impede root growth (Nyamangara et al., 2007). Although some heavy metals are essential for plant growth (e.g. Zn and Cu), they are toxic to plants above certain thresholds and can remain in the soil indefinitely. The health risks associated with domestic sewage sludge were higher in women as they constituted the largest proportion that used this organic resource to fertilize their crops.

The use of ridges and furrows is common with farmers and can result in increased yields by not only conserving soil moisture but also by reducing nutrient loss due to erosion and increasing plant rooting depth (Critchely, 1991). In wetland areas, farmers used wide raised beds that resulted in reduced water logging and soil loss. Mulching with grass and maize stover conserves soil moisture by reducing evaporation from the soil (Critchely, 2010). In Chitungwiza (sandy soils), maize yield was significantly higher where water management practices were used because rainwater collects in the furrows and can be available in times of low rainfall (Ibraimo and Munguambe, 2007). In Harare (clay soils), however, use of water management practices depressed maize yield. Clay soils do not drain freely and are prone to water logging which impedes root respiration and nutrient uptake. Therefore water management practices need to be targeted according to soil type and training in such management practices should target women farmers as most of them applied these practices.

Contrary to studies carried out in greater Garborone, Botswana where UA was gender balanced (Hovorka 2005), UA in Harare and Chitungwiza was not. Women constituted the majority of farmers in Harare and Chitungwiza as in many developing countries for example Windhoek in Namibia, 54% (Hovorka, 2004) and Oshakati 58% (Dima et al., 2002). This is because in most developing cities in sub- Saharan Africa, men feature prominently in middle- and high-income categories, while women are concentrated in lower-income brackets hence for most of them farming is their main source of livelihood (Wilbers, 2004; Mawoneke and King, 2005). In this study male farmers were more able to hire tillage services, and application of more cattle manure and mineral fertilizer. According to Kasanga (2001), women are more likely to use organic amendments to grow food crops and are constrained by a cycle of low productivity from investing in further farm development. Men on the other hand are likely to use technologies that may include use of inorganic fertilizers because most have alternative sources of income to buy fertilizers and also get extra income from the sale of excess crops whilst most women have no extra income because they mainly practice subsistence farming (Wilbers, 2004; WOGAN, 2009). In Senegal, women are deeply involved in the management of manure and other household waste for disposal in the family manure pile (*sëntaare*) (McClintock, 2004).

Overall farmers in Chitungwiza and Harare applied sub-optimal fertilizer rates and consequently their maize grain yields were low. Both towns are located in a high rainfall zone and farmers can substantially increase yields by increasing fertilizer use. The fertilizer rates were much lower for women farmers, as most of them lacked resources to purchase animal manure and mineral fertilizer. Water management practices and use of domestic sewage sludge, which were practiced by more women farmers, did not seem to give yield advantages to the women farmers.

CONCLUSION AND RECOMENDATIONS

Farmers in Harare and Chitungwiza used sub-optimal fertilizer application rates and this resulted in low yields. The use of fertility inputs was gendered with more women than men using the organic manures and men using the relatively more expensive but more effective mineral fertilizer. The use of water management practices was also gendered and was practiced by more women than men, but positive yield responses were only recorded on sandy soils. There is need to train the urban farmers to apply adequate amounts of nutrient inputs (organic and inorganic) and use appropriate water management technologies, with a special focus on female farmers.

Conflict of Interest

The authors have not declared any conflict of interest.

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REFERENCES

Bowyer-Boyer TAS, Drakakis-Smith D (1996). The needs of the urban poor versus environmental conservation': Conflict in urban

agriculture. Research report, ODA Project R5946. London.
Chen J (2008). The combined use of chemical and organic fertilizers and/or bio fertilizer for crop growth and soil fertility'. Technical report for Food and fertilizer technology Centre, Taiwan.
Critchley W (1991). Looking after our land. New approaches for soil and water conservation in dryland Africa. Oxfam Publication, Oxford, UK, pp. 8-17. http://dx.doi.org/10.3362/9780855987879.
Critchley W (2010). Handbook of catchment Management. World association of soil and water conservation. Eds: Ferrier, R.C. and Jenkins A. Wiley-Blackwell Publication.
Dima SJ, Ogunmokun AA, Nantanga (2002). The status of urban and periurban agriculture, Windhoek and Oshakati, Namibia.ftp://ftp.fao.org/sd/sdww/nam_periurban_02.pdf
Drescher AW (1994). Urban Agriculture in seasoned tropics of Central Southern Africa. A case study of Lusaka, Zambia'. Paper presented at the International Policy Workshop on Urban Agriculture. A growing development tool. University College, London NM/CPU 29 June 1994.
FAO (2006). Fertilizer use by crop in Zimbabwe. Food and Agriculture Organisation of the United nations, Rome, Italy, P. 35.
FAO (2002). Urban Agriculture and Peri-urban Agriculture: A Briefing Guide for Successful Implementation of Urban Agriculture and Peri-urban Agriculture in and Countries of Transition. FAO, Rome, Italy.
FAO/UNESCO (1998). World reference base for soil resources (http://en.wikipedia.org/wiki/FAO soil classification).
Hovorka AJ (2004). Commercial urban agriculture in Greater Gaborone: form and function, challenges and prospects'. Pula: Bot. J. Afr. Stud. 18(2):80–94.
Hovorka AJ (2005). 'Gender, commercial urban agriculture and urban food supply in Greater Gaborone, Botswana', in Mougeot, L. J. A (ed) AGROPOLIS: The Social, Political and Environmental Dimensions of Urban Agriculture, International Development Research Council, Ontario, Canada pp. 137-152.
Ibraimo N, Munguambe P (2007). 'Rainwater Harvesting Technologies for Small Scale Rainfed Agriculture in Arid and Semi-arid Areas'. Report on the Limpopo Basin (Project CP. 17). Waternet.
Kasanga K (2001). 'Peri-urban urbanization and land markets and gender insecurity under matrilineal property rights'. In: Ishani, Zanina and Lamba, Davinder (eds), Emerging African research on gender, urbanization and environment. Magazine Institute, Nairobi.
Kisner C (2008). Urban Agriculture case study, Harare, Zimbabwe. Green roofs for urban food security and environmental sustainability. Climate Institute, Washington DC (www.climate.org/topics/international-action/urban.../harare.htm).
List of cities and towns in Zimbabwe (2010) (http://en.wikipedia.org/.../List_ of_ cities_ and _towns_ in_ Zimbabwe).
Mapanda F, Mangwayana EN, Nyamangara J, Giller KE (2005). The effect of long term irrigation using wastewaters on heavy metal contents of soil under vegetables in Harare, Zimbabwe'. Agric. Ecosyst. Environ. 107:151-165. http://dx.doi.org/10.1016/j.agee.2004.11.005
Mawoneke S, King B (2005). Impact of Urban Agriculture Research in Zimbabwe'. Cities Feeding People Programme of the IDRC.
Mbiba B (1995). Urban Agriculture in Zimbabwe: Implications for Urban Management and Poverty'. Avebury, Aldershot.
Mbiba B (2000). Urban Agriculture in Southern and Eastern Africa: Policy Questions and Challenges'. In: David Grossman, Leo M van den Berg, and Hyacinth I Ajaegbu (eds.) Urban and Peri-Urban Agriculture in Africa. Proceedings of a workshop in Netanya, Israel, 23-27 June 1996 Aldershot: Ashgate Publishing Ltd. pp. 297-305.
Mudimu GD (1996). Urban agriculture activities and women's strategies in sustaining family livelihoods in Harare, Zimbabwe', Singapore J. Trop. Geogr. 17(2):179–194. http://dx.doi.org/10.1111/j.1467-9493.1996.tb00092.xPMid:12322325
Nhamo N, Murwira HK, Giller (2004). 'The Relationship Between Nitrogen Mineralization Patterns and Quality Indices of Cattle Manures from Different Smallholder Farms in Zimbabwe'. In: Managing Nutrient Cycles to Sustain Soil Fertility in Sub-Saharan Africa, Bationo, A. (Ed.). Academy Science Publishers and TSBF-CIAT, Nairobi, pp. 299-315.
Nyamangara J, Mugwira LM, Mpofu SE (2000). Soil fertility status in the communal areas of Zimbabwe in relation to sustainable crop production. J. Sust. Agric. 16:15-29. http://dx.doi.org/10.1300/J064v16n02_04
Nyamangara J, Munotengwa S, Nyamugafata P, Nyamadzawo G (2007). 'The effect of hydroxide solutions on the structural stability and saturated hydraulic conductivity of four tropical soils'. South Afr. J. Plant Soil 24(1):1-7. http://dx.doi.org/10.1080/02571862.2007.10634773
Nyamangara J, Mzezewa J (1996), 'Maize growth and nutrient uptake in a Zimbabwean red clay soil amended with anaerobically digested sewage sludge'. J. Appl. Sci. Southern Afr. 2(2):83-89. http://dx.doi.org/10.4314/jassa.v2i2.16879
Okalebo JR, Gathua KW, Woomer LP (2002). Laboratory methods of soil and plant analyses. A Working Manual, Agrobios.
Overholt CA (1991). Gender analysis framework', In Rao, A., Anderson, M. B. and Overholt, C. A. (eds), Gender Analysis in Development Planning, Kumarian Press: West Hartford, CT.
Tandi NK, Nyamangara J, Bangira C. (2004). 'Environmental and potential health effects of growing leafy vegetables on soil irrigated using sewage sludge and effluent : A case for Zn and Cu'. J. Environ. Sci. Health B39(3):461-471.
Toriro P (2007). Town planning in Zimbabwe: History Challenges and the urban renewal Operation Murambatsvina and Operation Garikayi', OSSREA: Harare.
Toriro P (2009). The impact of the economic meltdown on Urban Agriculture in Harare'. RUAF-Urban Agric. Magaz. P. 21.
Wilbers J (2004). Urban Agriculture and gender: some key issues'. Unpublished Discussion Paper 1, RUAF: Leusden, Netherlands.
Women organizing for change in Agriculture and NRM (WOGAN). (2009), 'Women feeding cities Mainstreaming Gender in Urban Agriculture and food security'. Practical Action Publishing, Rubby: UK.

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A comparison of predicted and measured pesticides concentrations in runoff of cotton farms in Brazil

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The adjustment and evaluation of methods which allow estimation of runoff and the concentration of associated pesticides are important for the development of prognostics studies in agricultural areas, mainly in tropical regions. In this context, this study aimed to adjust a method to estimate the concentration of pesticides in run-off applied to a cotton plantation farm, located in the micro-region of Primavera do Leste – MT (Mato Grosso State) in Central-Western Brazil. The method was based on the association of the model of pesticides concentration in run-off, described by OECD (1999), with the methods of Curve Number (CN) and Water Balance on Soil Surface (BW) to estimate the run-off amount. The pesticides, diuron, alfa and beta endosulfan, metolachlor, were selected based on the frequency and applied amount in cotton crops. Among the studied pesticides, diuron was the one for whom the adjusted method performed better in the studied scenarios, in others words, the best performance of the SFIL for prediction the pesticides concentrations greater than 3 µg L^{-1}. Thus the association of the OECD model to BW or CN performed well to predict the risk of surface waters contamination in cotton crop areas in tropical regions.

Key words: Modeling, contamination, surface waters, solute transport, tropical regions, agricultural areas.

INTRODUCTION

Several authors have reported environmental models as methods to estimate pesticides concentrations in surface or groundwater (Leonard et al., 1987; Berezen et. al., 2005; Swarcewicz and Gregorczyk, 2013; Fantke et al., 2013). The evaluation of a chemical's distribution and fate in the environment is an essential component of a risk assessment procedure (Pinho et al., 2006; Swarcewicz and Gregorczyk, 2013).

Despite the existence of several studies of environmental models application in many countries, in Brazil they are scarce and recent (Plese et al., 2009). Many papers emphasize that in regions of Brazil where agricultural production is intensive, mainly in cotton farms areas, it is necessary to evaluate environmental dynamics of pesticides (Pinho et al., 2004; Please et al., 2009). In this context, environmental models are very useful tools, since their use allows the evaluation of pesticides dissipation in soil. This information can be used to propose measures to mitigate the environmental impacts. In addition, literature indicates that in tropical

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Table 1. Description of the chemical and physical characteristics of the monitoring units

Localization	Soil	Management	S%[1]	DP[2] (m)	Clay	Silt	Sand	OC[3]
						g kg^{-1}		%
Chico Nunes small watershed	Yellow latosol	With filter strip of the *Brachiaria decumbens* with width of 10 m (MUS)	3..9	10 × 40	372	108	520	2.00
		Without strip filters *B. decumbens* (MWS)	4..1	10 × 40	461	107	432	3.00
Ilha small watershed	oxisol	Tillage system (MUC)	3..4	3.5 × 11	457	65	478	3.00
		No-tillage system (MUT)	2..9	3.5 × 11	414	95	491	4.27

[1]Slope of the monitoring units. [2]Dimensions of the monitoring units (width × length); [3]Percentage of the organic carbon in the surface layer of the soil (0-20 cm).

regions with cotton industry several pesticides have been detected in surface water and among the innumerous factors that affect pesticides runoff, the agricultural management system is a very important one (Carbo et al., 2008).

Moreover, many studies point out that there is high risk of the environmental contamination of some pesticides, such as, α and β-endosulfan, diuron and metolachlor (Weaver et al., 2012; Kennedy et al., 2001; Barrett and Jaward, 2012). In addition, literature indicates that in tropical regions with cotton industry several pesticides have been detected in surface water and among the innumerous factors that affect pesticides runoff, the agricultural management system is a very important one (Carbo et al., 2008; Casara et al., 2012). Hence, it is necessary to study the influence of the management systems in the dynamics of the pesticides in the environment

The present study, therefore, aimed to adjust a model by combination of the pesticide concentration model, reported by OECD (1999), with Runoff Curve Number (RCN) developed by the USDA Natural Resources Conservation Service (SCS-USDA), and the water balance in soil surface (WB) describe by Pruski et al. (1997) to estimate the concentrations of α- and β-endosulfan, diuron and metolachlor in runoff.

MATERIALS AND METHODS

Investigation area

The experiment consisted of installing four monitoring units in two farms located in the micro-region of Primavera do Leste, Mato Grosso State, Central-Western Brazil, one farm situated near the riverside of Chico Nunes stream and another close to the riverside of Ilha stream, both tributaries of the Mortes River (Table 1).

On the first farm, two units were installed to monitor runoff in cotton cultivated areas. In one of them, one filter strip planted with *Bracchiaria* grass was set up at the low end of the monitoring unit. On the second farm, two runoff monitoring units were installed in areas cultivated with cotton. In one, it was used the tillage system and in the other one, the no-tillage system. In the four units, a runoff collector was installed at the low end. These collectors were formed by a gutter linked to a polyvinyl chloride pipe. The structure of the collector was directed to the lower end of the experimental plot that consisted on a rectangular container (Figure 1), built from galvanized sheet, coated with a filtering system (geotextile blanket). In this container there was a “Geib” type divisor, with nine openings, and in the central opening it was linked to a water tank that stored the runoff volume that had passed by the 1/9 fraction on the Geib aluminum gutter.

Runoff samples were collected at intervals of approximately 15 to 20 days. Water and sediment samples were collected in 1 L amber bottle and plastic bags, respectively. Samples were transported in ice boxes to the laboratory where they were kept under refrigeration (4°C) until analysis.

The collection period, from December 2006 to May 2007, that coincides with the period of heaviest rains in the region and pesticides application. The precipitation rate was obtained by pulse pluviographs installed in each of the monitoring farms.

Water sampling and pesticide analysis

Analysis of pesticides residues by gas chromatography

The residues of alfa and beta endosulfan and metolachlor in the water, were analysed using the method reported by Laabs et al. (2002) that used solid phase extraction with octadecilsylane (C18) cartridge (1000 mg) BakerbondTM, Mallinckrodt Baker, USA, previously conditioned with 10 ml of methanol and 10 ml of water, followed by elution with subsequent portions 10 ml of ethyl acetate, 10 ml of hexane: ethyl acetate (1:1) and 5 ml of hexane. The extract was concentrated in a rotary evaporator to near dryness and so transferred to an autosampler vial with toluene. A gas chromatograph HP-6890 with mass selective detector HP-5973 (Agilent GmbH, Germany), split/splitless injector, automatic sampler and a HP-5MS (5% phenylmethylsiloxane) column (30 m × 250 μm id × 0.25 μm phase thickness) was used for pesticide analysis. Pesticide residues were quantified by GC-MS operated in the selected ion monitoring mode at the following conditions: Injector block temperature: 250°C; carrier gas of helium (99,999% pure), gas flow of 1 ml min^{-1}; split/splitless injector operated in splitless mode; injection volume of 1 ml; oven temperature program with initial temperature of 92°C held for 2.5 min, heating up to 175°C at 15°C min^{-1}; 175°C held for 13 min, heating up to 280°C at 20°C min^{-1}, 280°C held for 9 min; and transfer-line temperature at 290°C. Pesticides were identified by retention time and relative abundance of three major ions from mass spectra of each substance (Table 2). Maximum tolerance for confirmation was specified as 20% of relative ion intensity response.

Analysis of pesticides residues by liquid chromatographic

Diuron residues in water was analysed according to the method

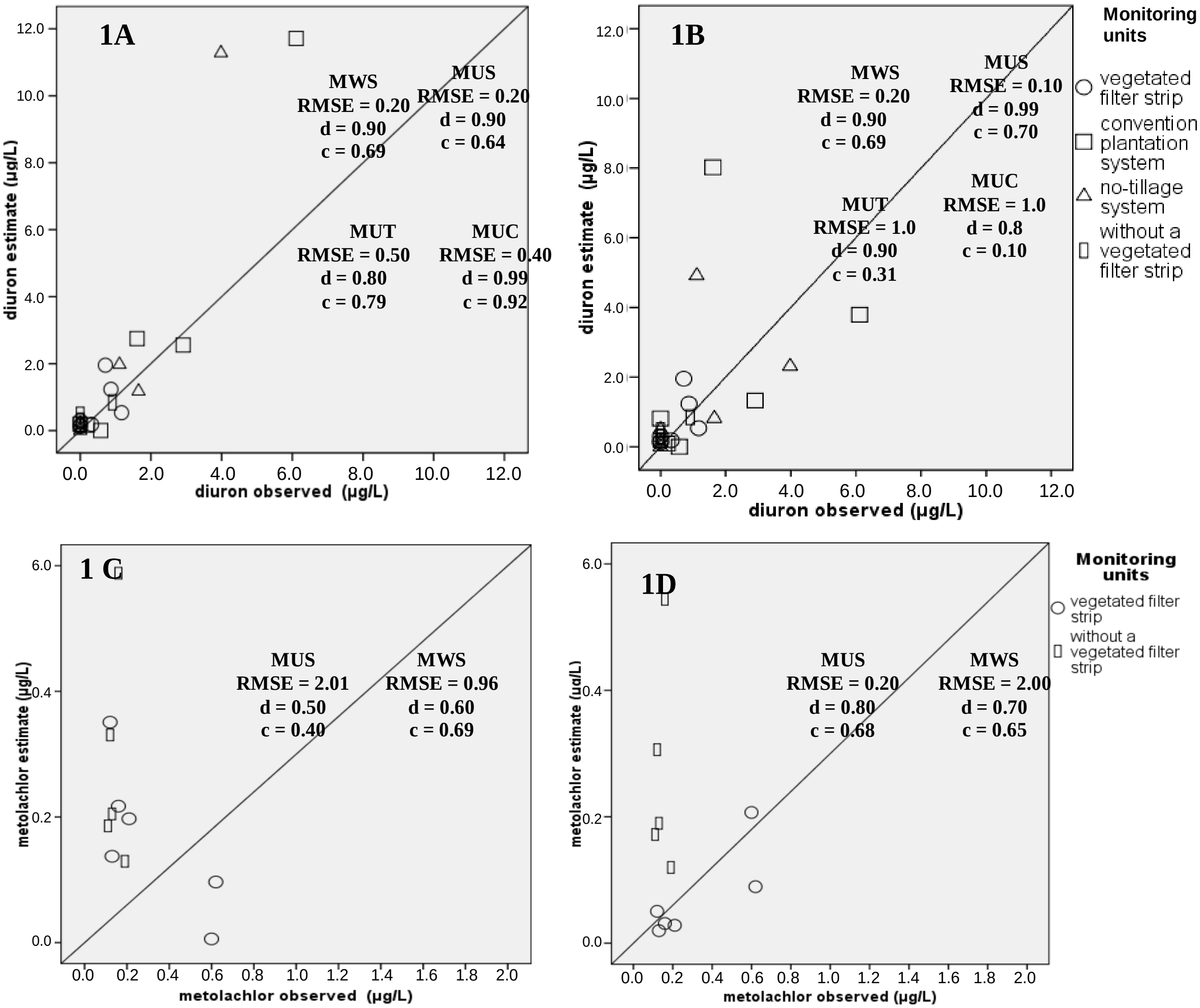

Figure 1. Predicted pesticide concentrations by SFIL Combined with RCN - Runoff *Curve Number (1A and 1C);* Predicted pesticide concentrations by SFIL Combined with WB - water balance in the soil surface (1B and 1D); MUS - Monitoring units with strip filter of the *B.*; MWS - without strip filter of the *B. decumbens*; MUC - Monitoring unit with Conventional system; MUT - Monitoring unit with no-tillage system.

Table 2. Monitoring ions for identification and quantification of the pesticides by GC/EM

Pesticides	Target ion	Fisrt ion	Second ion
Alpha endosulfan	241	238	195
Beta endosulfam	207	195	237
Metolachlor	162	238	240

described by Carbo et al. (2008). Aliquots of 500 ml of the samples were extracted in a SDVB cartridge (Envi-Chrom P, Supelco) previously conditioned with methanol. Then, the cartridge was dried, leaving the vacuum pump on for 30 min. Diuron was eluted with 3 × 5 ml of methanol:acetonitrile 7:3 (v/v) at a flow-rate of about 1 ml min^{-1}. The combined fractions were concentrated in a rotary evaporator (45°C) and the residue was redissolved in 1 ml of acetonitrile, followed by the addition of 50 µl of standard terbuthylazine solution (100 µg ml^{-1}) to the vial.

The analysis was performed with a Varian HPLC system equipped with a 410 autosampler, a 240 quaternary pump and 330 UV diode-array detector linked to a personal computer running the

Table 3. NRCS runoff curve numbers (CN).

Cover type	Treatment	Hydrologic condition	Curve numbers for hydrologic soil group			
			A	B	C	D
Fallow	Bare soil	-	77	86	91	94
	Crop residue cover (CR)	Poor	72	81	88	91
		Good	67	78	85	89
Row crops	Straight row (SR)	Poor	70	79	84	88
		Good	65	75	82	86
	Contoured and terraced (C and T)	Poor	66	74	80	82
		Good	62	71	78	81
Small grain	SR	Poor	65	76	84	88
		Good	63	75	83	87
	SR + CR	Poor	64	75	83	86
		Good	60	72	80	84
	C	Poor	63	74	82	85
		Good	61	73	81	84
	C + CR	Poor	62	73	81	85
		Good	60	72	80	83
	C+T	Poor	61	72	79	82
		Good	59	70	78	81
	C+T+CR	Poor	60	71	78	81
		Good	58	69	77	80
Close seeded or broadcast legumes or rotation meadow	SR	Poor	66	77	85	89
		Good	58	72	81	85
	C	Poor	64	75	83	85
		Good	55	69	78	83
	C+T	Poor	63	73	80	83
		Good	51	67	76	80

Fonte: Iowa Storm water Management Manual, 2008.

software program Varian ProStar, version 5.5 (Varian, USA). The analytical column (250 mm × 4.6 mm I.D.) used here was an Omnisphere 5 µm C_{18}, and the guard column (20 mm × 4.6 mm I.D.) was also an Omnisphere 5 µm C_{18}. For the HPLC analysis, an aliquot (10 µl) was injected into the column and eluted at room temperature at a constant flow-rate of 1 ml min^{-1} under the following conditions.

The analyte was eluted with acetonitrile:water that in the initial composition is 18% acetonitrile, increasing to 40% at 6 min, 80% at 35 min, 90% at 40 min, and 100% acetonitrile at 45 min, when it was kept constant for 3 min and then linearly decreased to the initial analysis conditions in 10 min. The detection and quantification were performed at 230 nm. Diuron was identified by its retention time and identification was confirmed by comparison of its UV spectrum.

Balance water in the soil surface (WB)

The model of the water balance in the soil surface (Equation 1) assumes: uniform precipitation in the study area; soil moisture next to saturation and null evaporation since it is very small during rainfall.

$$ES = PT - I_a - I - e_v \quad (1)$$

ES = runoff, mm; PT = total precipitation, mm; Ia = initial abstractions, mm; I = cumulative infiltration, mm; e_v = evaporation, mm.

The total precipitation (PT) was obtained by rain gauges installed in the experimental areas.

The initial abstractions (surface water until runoff start) depend on interception, depression storage and infiltration before of the runoff. The values of I_a were estimated by RCN (Equation 2), according to the Soil Conservation Service – SCS (1972):

$$I_a = 50,8\left(\frac{100}{CN} - 1\right) \quad (2)$$

CN = Curve Number

The values of CN were obtained by the method described on Soil Conservation Service (1972) (Table 3). According to Pruski et al. (1997), the hydrological conditions, in others words, the soil surface type can be considered:

1. Good condition: grass cover of 75% or more of the area;
2. Fair condition: grass cover of 50 to 75% of the area;
3. Poor condition: grass cover of 50% or less of the area.

The soil cover for the several scenarios of simulation was estimated from the post-emergence days and percentage of plant cover, according to Silva et al. (2004) (Equation 3):

Plant cover (%) = 46.07 ln(post-emergence days) -115.1; R^2 = 0.962 (3)

From Equation (3), at the experimental conditions, it was determined that:

1. Until 36 post-emergence days, 50% of the plant cover, bad condition.
2. From 36 post-emergence days and on, 75% of plant covers, good condition.

The cover type and treatment of surface soil observed in Table 3 for several scenarios of the simulation are briefly described as follows:

(i) The treatment considered in experimental areas was small grain; (ii) The area with butter strip was considered straight row with contoured and terraces and (iii) other experimental areas were considered only contoured.

The soil properties (Table 1) most similar to that of the experimental area were C type: Low infiltration rate when thoroughly moist, layer impediment and with considerable percentage of clay.

The corresponding time for occurrence of the initial abstractions was obtained by the Equation 4:

$$t_{I_a} = \frac{I_a.60}{i_m} \quad (4)$$

t_{Ia} = Time interval between the onset of rain and runoff initiation, min; I_m = Average rainfall intensity, mm; The duration of infiltration was obtained by the Equation 5.

$$t_{inf} = t - t_{I_a} \quad (5)$$

t = Total time of rainfall, min.

The water evapotranspired and evaporated (e_v) during the precipitation was considered negligible, in view of the low vapor pressure.

Runoff curve number (CN)

According to Pruski et al. (2006), the runoff curve number method (Equation 6) is one the most important methods of the estimate the runoff:

$$ES = \frac{(PT - 0,2S)^2}{(PT + 08S)} \quad (6)$$

ES = runoff, mm; PT = = total precipitation, mm; S = infiltration potential, mm (Formula 7).

$$S = \frac{25400}{CN} - 254 \quad (7)$$

CN = Runoff curve numbers (Table 3).

Prediction of pesticide concentrations

The model for the prediction of pesticide concentrations (Equations 8 and 9) was adapted based on the ones described in the Project "Pesticide Aquatic Risk Indicator" by OECD (1999), and on that reported by Berenzen et al. (2005).

The model assumes that:

1. The rainfall takes place 3 days after pesticides application (OECD, 1999; Berenzen et al., 2005)
2. Due to the fact that the model was calibrated under field conditions, we considered that there was enough time for pesticide equilibration between the solid and liquid phase of the soil.

$$L\%_{runoff} = \frac{ES.f.e^{\frac{-3\ln 2}{t_{1/2}}}}{P} \cdot \frac{100}{1+K_d} \quad (8)$$

L%runoff = Percentage of application dose that is present in runoff water as a dissolved substance; *ES* = estimated runoff by method WB or CN (mm); f = Correction factor, $f = f_1.f_2.f_3$ (modified equation of Beinat and van der Berg, 1996); f_1= Slope factor: if slope (d)< 20% - $f_1 = 0,02153.d + 0,001423.d^2$; if slope (d)≥ 20% - f_1= 1; f_2 = Buffer zone factor. f_2 = $0,83^{WZB}$, with WBZ – width of the buffer zone (m); if the buffer zone is not densely covered with plants then the width is set to zero (Berezen et al., 2005) ; f_3= plant interception factor estimated by Equation (3). (1 - %plant cover/100); *P* = Precipitation amount (mm). DT_{50} = Half-life of active ingredient in soil (days); K_d = Ratio of dissolved to sorbed pesticide concentrations (mL g^{-1}).

The mean pesticide concentration in the runoff was then calculated using Equation (9):

$$P_C = L\%_{runoff}.Pa\,\frac{1}{ES} \quad (9)$$

P_c = Predicted pesticide concentration (µg L^{-1}); Pa = amount of pesticide applied in the cotton farm in the experimental plot (µg); *ES* = estimated runoff by method WB or CN (mm).

Tables 4 and 5 show the doses of the pesticide applied in the experimental plots under field conditions, in cotton areas cultivated under different management systems: with and without a vegetated filter strip (buffer filter) planted with *Bracchiaria* grass and no-tillage system (direct seeding) and conventional soil preparation.

The physical properties of the pesticides that were used for the prediction in the model are shown in Table 6. They were obtained for tropical soil conditions, aiming to improve the model performance.

RESULTS

Estimated runoff by *curve number* (RCN) and water balance in the soil surface (WB)

The runoff depth estimated by Curve Number (RCN)

Table 4. Doses of the pesticide applied in experimental in cotton groups cultivated with and without a vegetated filter strip

Active ingredient	Dates of the pesticides application	Average dosage per hectare	Pesticides applied in experimental plots (g)
Diuron	01/01/2007	1.0 kg ha^{-1}	32.00
Diuron	01/01/2007	0.8 L ha^{-1}	32.00
Diurom	01/01/2007	0.8 L ha^{-1}	16.00
α-endosulfan	07/02/2007	2 L ha^{-1}	14.70
B-endosulfan	07/02/2007	2 L ha^{-1}	6.30
α-endosulfan	19/02/2007	2 L ha^{-1}	14.70
β-endosulfan	19/02/2007	2 L ha^{-1}	6.30
Metolachlor	01/01/2007	0.6 L ha^{-1}	23.4

Table 5. Doses of the pesticide applied in experimental in cotton groups cultivated with no-tillage system (direct seeding) and conventional soil preparation

Active ingredient	Dates of the pesticides application	Average dosage per hectare (L ha^{-1})	pesticides applied in experimental plots (g)
Diuron	22/12/2005	0.68	2.9440
		0.26	0.8008
		0.51	0.1963
		0.11	0.42350
		0.08	0.3080
α-endosulfan	31/01/2006	1.50	1.4148
	11/03/2006	2.00	1.8865
	21/03/2006	2.00	1.8865
	27/03/2006	2.00	1.8865
β-endosulfan	31/01/2006	1.50	0.6063
	11/03/2006	2.00	0.8085
	21/03/2006	2.00	0.8085
	27/03/2006	2.00	0.8085

Table 6. Physical properties of the pesticides

Pesticides	Ratio of dissolved to sorbed pesticide concentrations K_d (g mL^{-1})*	Sorption coefficient of active ingredient to organic carbon K_{oc} (g mL^{-1})*	Half-life of active ingredient in soil $t_{1/2}$ (dias)*	Water Solubility S_w (mg.L^{-1})
Diuron	14.3	916.7	15	36.4[d]
α-endosulfan	288	22040	43	0.33[e]
β-endosulfan	405	25961	128	0.32[e]
metolachlor	3.1	198.7	34	5.30[f]

*Tropical soil conditions, values obtained in laboratory; d - Moncada, (2004); e - Fan (2007); f – Rivard (2003).

(Table 7) was higher than the observed values in all units with exception of the monitoring unit with conventional system (MUC). These overestimated values were less significant in the unit with no-tillage system (MUT). As for the Water Balance in the Soil Surface method (WB), an overestimation in runoff was observed for the units with and without filter strip of the *Brachiaria decumbens*. On the other words, for the MUC and MUT units, an underestimation was observed, with a higher runoff depth in the MUC in relation to the MUT unit (Table 7).

Table 7. Observed runoff (R-OBS) and estimated runoff (R-EST) by the prediction methods of Balance water in the soil surface (WB) and Runoff Curve Number (RCN) for the experimental areas

Monitoring units	R-OBS	R-RCN	R-WB
	AR[1]	AR	AR
		mm	
MUS	14.69	286	324.4
MWS	121.58	366	324.4
MUC	319.45	194.7	144.8
MUT	183.07	194.7	86.5

[1]Average runoff; MUS - Monitoring units with strip filter of the *B. decumbens*; MWS - without strip filter of the *B. decumbens*; MUC - Monitoring unit with conventional system; MUT - Monitoring unit with no-tillage system.

Therefore, the WB method represented better the effect of culture systems.

Comparison of the prediction with measured data

In Figure 1A, the relationship between pesticide concentration predicted by the SFIL model associated with RCN or WB and measured diuron concentrations is shown. A greater dispersion of predicted diuron concentrations was observed in the different evaluated scenarios when RCN for runoff prediction was used. In general, there was a predominance of underestimation of diuron concentrations in the monitoring unit with strip filter of the *B. decumbens*, regardless of the methodology used to runoff prediction. It was also observed that there were overestimated and underestimated concentrations for α-endosulfan when the SFIL was combined with RCN or WB (Figure 2). Differently, as for β-endosulfan (Figure 2) an underestimation tendency of the concentration predicted by SFIL for all evaluated scenarios was observed in both methods for runoff prediction. Among the studied pesticides, metolachlor was the pesticide that showed the most overestimation tendency for the concentrations predicted by SFIL combined with RCN or WB (Figure 1C and D).

Statistical analyses

The relationship between predicted pesticides concentrations by SFIL with different methods of runoff prediction (Table 8) or scenarios (Table 9) and measured pesticide concentrations was analyzed using Student's t-test when it was possible to get normal distribution. For the variables that that were not normally distributed, the non-parametric test of Wilcoxon was used. For all statistical analyses the software SPSS 15.0 was used. Moreover, it was evaluated the determination coefficients (R^2) between predicted and observed pesticides concentrations irrespective of methods of runoff prediction or scenarios (Table 10)

No significant differences between observed and predicted pesticide average concentrations by SFIL combined with RCN method for diuron and α-endosulfan were observed (Table 8). In addition, there were no significant differences between predicted pesticide average concentrations by SFIL combined with RCN and WB for metolachlor, α and β endosulfan, however, both of it were statistically different than experimentally observed values (Table 8).

The average concentrations of diuron predicted by SFIL combined with RCN method, with exception of the monitoring unit without strip filters *B. decumbens* (MWS), were not statistically different than experimentally observed values (Table 9). In relation to α-endosulfan, the predicted average concentrations in the monitoring units with and without filter strip of the *B. decumbens* (MUS and MWS) were statistically different, when the SFIL was combined with RCN method. Regarding β-endosulfan, in the MWS and MUC the predicted average concentrations were statistically different when compared to observed concentrations (Table 9).

DISCUSSION

Prediction of runoff

The monitoring units with and without a 10-m filter strip of *B. decumbens* (MUS and MWS) in cotton farm showed overestimation of the runoff by RCN or WB methods, nevertheless in relation the estimated runoff by RCN it was observed lesser values of estimated runoff for MUS when compared with MWS as well as also it was verified to observed runoff (Table 7), probably due to the higher basic infiltration rate (TIB) in the MUS than in the MWS. The presence of roots in the soil provide higher infiltration rate, moreover, the high surface roughness provided by vegetation reduces the runoff velocity, increasing

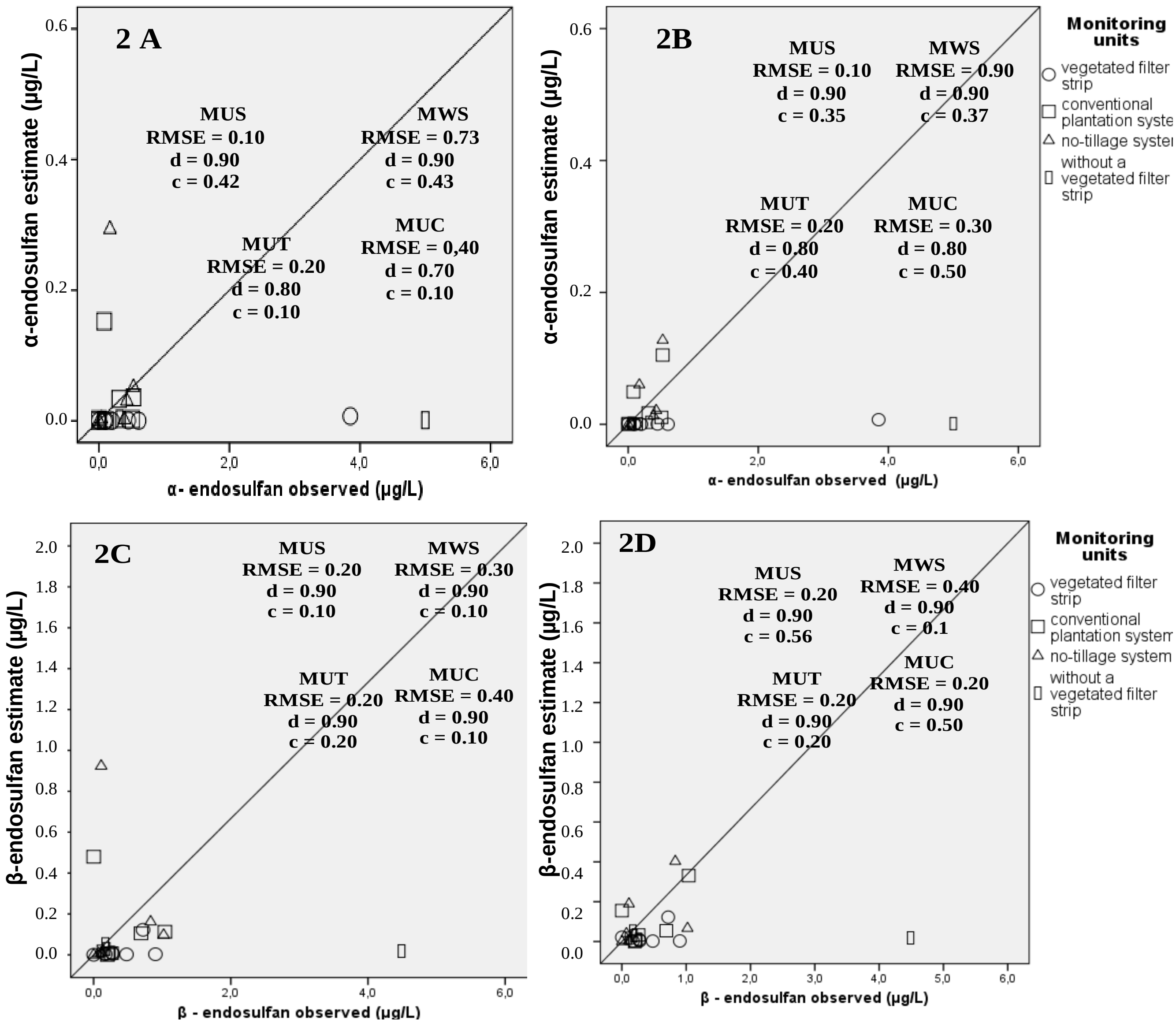

Figure 2. Predicted pesticide concentrations by SFIL Combined with RCN - Runoff *Curve Number (2A and 2C);* Predicted pesticide concentrations by SFIL Combined with WB - water balance in the soil surface (2B and 2D); MUS - Monitoring units with strip filter of the *B. decumbens*; MWS - without strip filter of the *B. decumbens*; MUC - Monitoring unit with Conventional system; MUT - Monitoring unit with no-tillage system.

Table 8. Comparison of the observed and predicted of pesticide concentrations by SFIL

Pesticidas	RCN	WB	OBS
	[1]Average concentrations (µg L^{-1})		
Diuron*	1.218^{A}	1.610^{B}	1.000^{A}
Metolachlor*	2.560^{A}	3.170^{A}	0.260^{B}
α -Endosulfan**	0.176^{AB}	0.259^{A}	0.578^{B}
β -Endosulfan**	0.065^{A}	0.091^{A}	0.523^{B}

[1]Means followed by the same letter in the same line do not differ at 5% probability;* Teste t-Student; ** Teste Wilcoxon; RCN – Runoff *Curve Number;* WB – water balance in the soil surface;OBS – Observed concentrations; MUS - Monitoring units with strip filter of the *B. decumbens*; MWS - without strip filter of the *B. decumbens*; MUC - Monitoring unit with Conventional system; MUT - Monitoring unit with no-tillage system.

Table 9. Comparison of the observed and predicted of pesticide concentrations by SFIL in several scenarios

Pesticides	MUS			MWS			MUC			MUT		
	[1]Average concentrations (μg L^{-1})											
	RCN	WB	OBS	RCN	WB	OBS	RCN	WB	OBS	RCN	WB	OBS
Diuron*	0.640^{A}	0.640^{A}	0.440^{A}	0.410^{A}	0.410^{A}	0.180^{B}	2.340^{A}	2.900^{A}	2.000^{A}	1.440^{A}	2.00^{A}	1.000^{A}
Metolachlor*	0.709^{A}	1.670^{A}	0.306^{B}	0.431^{C}	0.466^{C}	0.210D	nd	nd	nd	nd	nd	nd
α-Endosulfan**	0.004^{A}	0.002^{A}	0.243^{B}	0.023^{B}	0.024^{B}	1.571^{C}	0.372^{A}	0.633^{A}	0.260^{A}	0.305^{A}	0.377^{A}	0.238^{A}
B-Endosulfan**	0.007^{A}	0.003^{A}	0.35^{A}	0.041^{A}	0.041^{A}	0.998^{B}	0.117^{A}	0.199^{A}	0.356^{B}	0.096^{A}	0.118^{A}	0.400^{A}

[1]Means followed by the same letter in the same line do not differ at 5% probability;* Teste t-Student; ** Teste Wilcoxon; RCN – Runoff Curve *Number;* WB – water balance in the soil surface; OBS – Observed concentrations; MUS - Monitoring units with strip filter of the *B. decumbens*; MWS - without strip filter of the *B. decumbens*; MUC - Monitoring unit with Conventional system; MUT - Monitoring unit with no-tillage system.

Table 10. Determination coefficients (linear regression) between predicted and measured pesticide concentrations irrespective of methods of runoff prediction or scenarios

Pesticides	Determination coefficients (R^2)
Diuron	0.6038
α-endosulfan	0.0274
B-endosulfan	0.0040
Metolachlor	0.1081

hydraulic load, consequently providing the higher water infiltration. The predicted runoff by RCN or WB did not consider the different infiltration in the area with filter strip of *B. decumbens.*

Regarding the monitoring units with conventional system (MUC) and no-tillage system (MUT) an overestimation of the runoff was observed, nevertheless, the WB method performed better to describe the effect of the cultivation system in the MUC and MUT. In other words, in the MUC the predicted runoff was greater than in the MUT. This higher runoff values, both estimated and observed of the conventional system compared to no-tillage, is probably due to increasing soil sealing and consequent TIB decreasing caused by this management system (SCHICK et al., 2000).

Measurements of pesticide concentrations

The predicted diuron concentrations observed by SFIL combined with WB method showed Willmott index (d) described by Willmott et al. (1985) ranging from 0.99 to 0.80 (Figure 1A). The Willmott index indicates the degree of accuracy between the observed and predicted values. The Root Mean Square Error ranged from 0.2 to 0.5 (RMSE) (Figure 1A). According to Chung et al. (1999) these values of RMSE (0.2 to 0.5) are considered satisfactory. The performance of the SFIL was evaluated by performance index (c) (Camargo et al., 1997). The values of “c” ranged from medium (0.64) to optimum (0.9) (Figure 1). In relation to predicted diuron concentrations determined by SFIL combined with RCN, the “c” values ranged from 0.1 to 0.7 (Figure1 B) respectively, bad and good performance according to Camargo et al. (1997). The RMSE values were lower than 0.5 for MUS and MWS, however, in the MUC and MUT these values were higher, considered satisfactory and unsatisfactory, according to Chung et al. (1999).

For metolachlor, RMSE ranged from 0.2 to 2.00 (Figure 1C and D) values which are considered satisfactory and unsatisfactory, respectively, according to Chung et al. (1999). Moreover, when SFIL was combined with WB, the model performance can be considered bad (MUS) and good (MWS), but when SFIL was combined with RCN the model performance changed to medium (MUS) and good (MWS).

In addition, considering the mobility and solubility parameters shown in Table 10 according to FAO (2000) and persistence according to IBAMA (1990), it was observed that diuron and metolachlor (Table 11) are the most likely to suffer leaching compared to α- and β-endosulfan. In the SFIL model, leaching was not considered thus the overestimation of the predicted concentrations for these pesticides may be due to absence of leaching calculations by SFIL.

The SFIL model showed the worst performance for α- and β- endosulfan, with “c” values classified as too bad (0.1) and tolerable (0.5) (Figure 2). The RMSE ranged from 0.1 to 0.9 (Figure 2), and the Willmott index showed values close to one.

Table 11. Classification of the pesticides according to physical and chemistry properties

Proposed classification by IBAMA (1990)			
Half-life (days)		Classification	
< 30		Nonpersistent	
30 - 180		Moderately persistent	
180 - 360		Persistent	
> 360		Highly persistent	
Proposed classification by FAO (2000)			
Log K_{OC}	Classification		
<1	Highly mobile	Solubility - S_w (mg.L^{-1})	Classification
1 a 2	Mobile	< 0.1	Insoluble
2 a 3	Moderately mobile	0.1-1.0	Lightly soluble
3 a 4	Lightly mobile	1-10	Moderately soluble
4 a 5	Hardly mobile	10-100	Easily soluble
>5	Immobile	>100	Highly soluble
Pesticides	**Solubility S_w (mg L^{-1})**	**Sorption coefficient of active ingredient to organic carbon Koc (g mL^{-1})**	**Half-life $t_{1/2}$ (days)**
Diuron	Easily soluble	Moderately mobile	Nonpersistent
α-Endosulfan	Lightly soluble	Lightly mobile	Moderately persistent
β -Endosulfan	Lightly soluble	Lightly mobile	Moderately persistent
Metolachlor	Easily soluble	Mobile	Moderately persistent

The Table 10 shows that there was an better relationships (linear regression) between predicted and measured pesticide concentrations for diuron (R^2= 0.6038) than for others pesticides. From above results it can be inferred that the better performace of the SFIL is for high values pesticides concentrations as observed to diuron (Figure 1A and B), corroborates with Berezen et al. (2005) that reported the better performance of the SFIL in estimate concentration above 5 μg L^{-1}.

Conclusions

In summary, the SFIL model showed a good potential of the predict the pesticide concentrations in runoff when combined with the Runoff Curve Number or water balance in the soil surface method, mainly high values of pesticides concentrations as observed to diuron. In addition the SFIL model was efficient in predict the impact of the management systems on the pesticides concentrations in several scenarios, mostly in scenarios where there were strip filters.

Conflict of Interest

The authors have not declared any conflict of interest.

REFERENCES

Barrett K, Jaward FM (2012). A review of endosulfan, dichlorvos, diazinon, and diuron – pesticides used in Jamaica, Int. J. Environ.Health Res. 22:481-499. http://dx.doi.org/10.1080/09603123.2012.667794

Berezen N, Lentzen-Godding A, Probst M, Schulz H, Schulz R, Liess M. A (2005). Comparison of predicted and measured levels of runoff-related pesticide Concentrations in small lowland streams na as landscape level. Chemosphere 58: 683-691. http://dx.doi.org/10.1016/j.chemosphere.2004.05.009

Beinat E, Van der Berg R (1996). EUPHIDS, a decision support system for admission of pesticides. National Institute of Public Health and the Environment, Bilthoven.

Camargo AP, Sentelhas PC (1997). Avaliação do desempenho de diferentes métodos de estimativas de evapotranspiração potencial no Estado de São Paulo, Brasil. Revista Brasileira de Agrometeorologia 5: 89-97.

Carbo L, Souza V, Dores EFGC, Ribeiro ML (2008). Determination of pesticides multiresidues in shallow groundwater in a cotton-growing region of Mato Grosso, J. Braz. Chem. Soc. 19: 1111-1117. http://dx.doi.org/10.1590/S0103-50532008000600009

Chung SW, Gassman PW, Kramer LA, Williams JR, Gu R (1999).Validation of EPIC for Two Watersheds in Southwest. Center for Agricultural and Rural Development Iowa State University Ames, IA, 50011-1070.

Fan S (2007). Endosulfan risk characterization document. Volume III Environmental Fate -Department of Pesticide Regulation Environmental Monitoring Branch,.Sacramento, Califórnia. Available from: <http://www.cdpr.ca.gov.> Accessed on: 05/06/2013.

Fantke P, Wieland P, Wannaz C, Friedrich R, Jolliet O (2013). Dynamics of pesticide uptake into plants: From system functioning to parsimonious modeling. Environmental Modelling & Software 40: 316-324. http://dx.doi.org/10.1016/j.envsoft.2012.09.016

FAO (2000). Food and Agriculture Organization of the United Nations. Assessing soil contamination. Available at: <http//:www.fao.org/docrep/003/X2570E00.htm>. Accessed on 05/ 05/2013.

IBAMA - Brazilian Institute of the Environment (1990). Pesticides manual for evaluation of the ecotoxicity of chemical agents 2:80-90.

Iowa Storm water Management Manual (2008). Available at:

http://www.ctre.iastate.edu/pubs/stormwater/documents/2C-5NRCSTR-55Methodology.pdf Accessed on: 29/06/2013.

Laabs V, Amelung W, Pinto A, Wantzen M, Silva CJ, Zech W (2002). Pesticides in surface water, sediment, and rainfall of the Northeastern Pantanal Basin, Brazil. J. Environ. Q. 31:1636–1648. http://dx.doi.org/10.2134/jeq2002.1636

Kennedy IR, Sanchez-Bayo F, Kimber SW, Hugo L, Ahmad N (2001). Off-Site movement of Endosulfan from irrigated cotton in New South Wales. J. Environ. Q. 30:683–696. http://dx.doi.org/10.2134/jeq2001.303683x

Leonard RA, Knisel WG, Still DA (1987). GLEAMS:Groundwater Loading Effects of Agricultural Management Systems. Transactions of the ASAE. 30:1403-1418. http://dx.doi.org/10.13031/2013.30578

Moncada A (2004). Environmental fate of diuron. Environmental Monitoring Branch Department of Pesticide Regulation 1001 I Street Sacramento, CA 95812-4015. Available from: www.cdpr.ca.gov/docs/emon/pubs/fatememo/diuron.pdf Accessed on: 20/06/ 2013.

OECD (Organisation for Economic Co-operation and Development) (1999). Annex II. Report of the OECD Project Pesticide Aquatic Risk Indicators pp. 28–32. Available at: www.oecd.org/dataoecd/31/36/ 2078678.pdf Accessed on: 20/05 2013.

Pinho AP, Matos AT, Costa LM, Morris LA, Martinez MA (2006). Modeling of herbicide retention in riparian zones. Rev. Bras. Engenharia Agríc. Ambiental. 10:896-902.

Plese LPM, Silva CL, Foloni LL (2009). Distribution of environmental compartments of herbicides used in the cotton, coffee and citrus culture. Planta Daninha, Viçosa, MG 27:123-132.

Pruski FF, Ferreira PA, Ramos MM, Cecon PR (1997). Model to design level terraces. J. Irrig. Drain. Engineer. 123:8-12. http://dx.doi.org/10.1061/(ASCE)0733-9437(1997)123:1(8)

Pruski FF, Brandão VS, Silva DD da (2006). Escoamento superficial. Viçosa, MG: Editora UFV, 2° ed.

Rivard L (2003). Environmental Monitoring Branch / Department of Pesticide Regulation. Environmental Fate of Metolachlor. California. Available from: http://www.cdpr.ca.gov/docs/empm/pubs/fatememo/metolachlor.pdf Accessed on: 05/05/2013.

Silva AV, Monteiro JEB, Chiavegato EJ, Bernardes MS (2004). Incidence of the solar radiation in plants of cotton in three different rows. Available at: http://www.cnpa.embrapa.br/produtos/algodao/publicacoes/trabalhos_cba5/412.pdf Accessed on: 05/05/2013.

Schick J, Bertol I, Batistela O, Balminot Jr AA (2000). Soil erosion of a clayey inceptisol under different crop and tillage systems: ii. nutrient and organic carbon losses. Rev. Bras. Ciênc. Solo 24:427-436. http://dx.doi.org/10.1590/S0100-06832000000200019

Weaver TB, Ghadiri H, Hulugalle NR, Harden S (2012). Organochlorine pesticides in soil under irrigated cotton farming systems in Vertisols of the Namoi Valley, north-western New South Wales, Australia. Chemosphere 88:336-343. http://dx.doi.org/10.1016/j.chemosphere.2012.03.008

Willmott CJ, Ackleson SG, Davis RE, Feddema JJ, Klink KM, Legates DR, Odonnell J, Rowe CM (1985). Statistics for the evaluation and comparison of models. J. Geophys. Res. Oceans Ottawa 90:8995-9005. http://dx.doi.org/10.1029/JC090iC05p08995

Swarcewicz MK, Gregorczyk A (2013). Atrazine degradation in soil: effects of adjuvants and a comparison of three mathematical models. Pest Manage. Sci. 69(12):1346-1350. doi: 10.1002/ps.3510

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Full Length Research Paper

Growing degree-day sum and crop growth cycle duration for wheat cultivars at different sowing dates

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The wheat *Triticum aestivum* L. is one of the most important foods in the human diet due to its high nutritional value. The grains can be eaten as bread, noodles, pasta, cookies, among others. The cultivation of wheat in Brazil has high production potential; the southern is region responsible for the largest acreage in the country, due to its soil and climate more favorable for crop development. The objective of this study was to determine the growing degree-days sum and the relationship between the period length from sowing to physiological maturity and sowing dates of thirteen wheat cultivars. The data on wheat crop correspond to the harvests of 2007 to 2011. The treatments consisted of 13 wheat cultivars and 3 sowing dates. The data used for the analysis were: Total elapsed days from sowing to silking, to physiological maturity, and of the silking to physiological maturity, along with the growing degree-days sum for these periods, beyond grains yield and hectoliter weight. The results indicate that the average length of sowing to the silking was 71 days. For the period from silking to physiological maturity the average length was 54 days. The increase in length of time from sowing to the silking in cultivars sown in May 25th was due to the decrease in air temperature. The average of growing degree-days sum between the period from sowing to physiological maturity was 1487. The cultivars that stood out presenting a shorter period of silking to physiological maturity and high productivity were the cultivars CD 114, CD 120, CD 121, CD 122, CD 124 and Onix.

Key words: *Triticum aestivum* L.*,* thermal summation, vegetative development.

INTRODUCTION

Between genres of wheat grown, the *Triticum* contains about 30 species; among them the *Triticum aestivum* L., known as common wheat is the species of greatest commercial interest. Besides being part of the human diet, wheat can also be used in the animal feed, with great economic and nutritional importance. The culture is also used as a cover crop in the winter and as succession crops such as soybeans and corn, benefiting soil conservation

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avoiding erosion, and contributing to the family income (Abtrigo, 2006).

In Brazil, according to Conab (2013a), the harvest of 2012/2013 the area cultivated with wheat was approximately 1.90 million hectares, reaching an average yield of 2269 kg ha^{-1}. The yield was lower than the 2011 crop which reached 2672 kg ha^{-1}. The reduction in the productivity of the crop of 2012/2013 was due to the instability of the atmospheric weather, with heavy rainfall after a season of low humidity at the time of sowing (Conab, 2013b).

The instability of the atmospheric weather, as excess or lack of rainfall, marked variations in air temperature, among others, reinforce the needs of the knowledge regarding the development of the wheat crop, combining technology and production planning, seeking greater stability in production, maximizing productivity in areas already cultivated.

Degree-days or heat summation for the growth and development of plants is directly related to average daily temperature of the air. Accumulated during the daily period, the growing degree-days are calculated by the difference between the average daily air temperature and the minimum basal temperature. According to Streck and Alberto (2006) for wheat, basal minimum temperature increase is 5°C. The thermal requirements needed to achieve a particular crop growth stage, allow predicting adaptation to different regions and sowing dates suffering direct influence of environmental conditions (Ferolla et al., 2007).

Therefore the objective of this study was to determine the growing degree-days sum and the relationship between the period length from sowing to physiological maturity and sowing dates of thirteen wheat cultivars in Cascavel State of Paraná Brazil.

MATERIALS AND METHODS

The data on wheat crop were collected by the Cooperativa Central de Pesquisa Agrícola (COODETEC) and correspond to the harvests of 2006 to 2011. The experiment was conducted in the field, in the research center of COODETEC located in Cascavel in the State of Parana, Brazil.

Cascavel is located at 24° 56' 36 "South latitude and 53° 32' 15" west longitude, 700 m altitude. The climate is subtropical (Cfa) according to the Köppen classification, with average annual air temperatures ranging from 20 to 21°C and total rainfall between 1800 to 2000 mm annual (Caviglione et al., 200). The soil is a latosol red typical dystrophic (Embrapa, 2006). The climatological data were obtained from the meteorological station of the Instituto Tecnológico Simepar located in Cascavel, in the period from 2007 to 2011, in the months from April to September.

The experimental design was randomized blocks with plots consisting of 6 rows with 5 m long, spaced 0.20 m between rows. The factorial scheme was 13 × 3, repeated for 5 growing seasons from 2007 to 2011, whose treatments consisted of 13 wheat cultivars and three sowing dates (April 25^{th}, May 15^{th} and 25^{th}).

For the experiment we used the direct seeding over straw, performed mechanically. The seeding density used was 360 viable seeds per square meter for all cultivars. For all harvests dates of sowing were transformed into Julian Days (JD), which are obtained by counting the days of the year in sequence (Table 1).

Table 1. Dates of sowing in Julian days in the harvests from 2007 to 2011 in Cascavel, Brazil.

City	Harvests	Dates	Julian days
Cascavel	2007 to 2011	April / 25	115
		May / 15	135
		May / 25	145

Fertilization, control of pests, diseases and weeds were made according to technical recommendations (Coodetec, 2010). For this study we used data from cycle cultivars early CD 105, CD 114, CD 117 and CD 118, ranging from 115 to 120 days from emergence to physiological maturity and average cycle, CD 113, CD 115, CD 119, CD 120 , CD 121, CD 122, CD 123, CD 124 and Onix, ranging 120 to 141 days from emergence to physiological maturity.

The data used for the analysis were: Total elapsed days from sowing to the silking and to physiological maturity, and of the silking to physiological maturity, along with the growing degree-days sum for these periods, beyond grains yield and hectoliter weight (HW). The analysis of HW was determined according to the Rules for Testing Seeds (Brasil, 1992) and the results expressed in kg hL^{-1}.

The growing degree-days sum (GD) in each development stage of wheat crop were obtained by the following equation used by Oliveira et al. (2011). The equation uses the number of days in the period considered, the average air temperature in the same period and the minimum temperature basal crop growth.

$$GD = \sum_{i=1}^{n}(Ti - Tb)$$

Where: Ti = Average daily temperature (°C); Tb = Base temperature 5°C (Streck and Alberto, 2006), n = Number of days in the period considered.

The data collected were subjected to analysis of variance, occurring significant interaction cultivars x sowing dates, proceeded up the developments needed for the parameter evaluated. Means were compared by grouping averages of Scott and Knott (1974) for evaluation of the effects of cultivars, and regression analysis to verify the behavior of the parameters, according to the sowing dates for each cultivar, 5% probability.

The analysis of the data was performed since the ratio between the largest and smallest mean square residual was not more than seven (Pimentel-Gomes, 2009). Was too performed analyzed of correlation between parameters. Data processing and statistical analysis were performed using the SISVAR statistical software (Ferreira, 2011).

RESULTS AND DISCUSSION

The Figure 1a and b shows the variation average monthly of air temperatures (average, minimum and maximum), and average total rainfall in Cascavel. As shown in Figure 1a, the average minimum air temperature (14.2°C) occurred

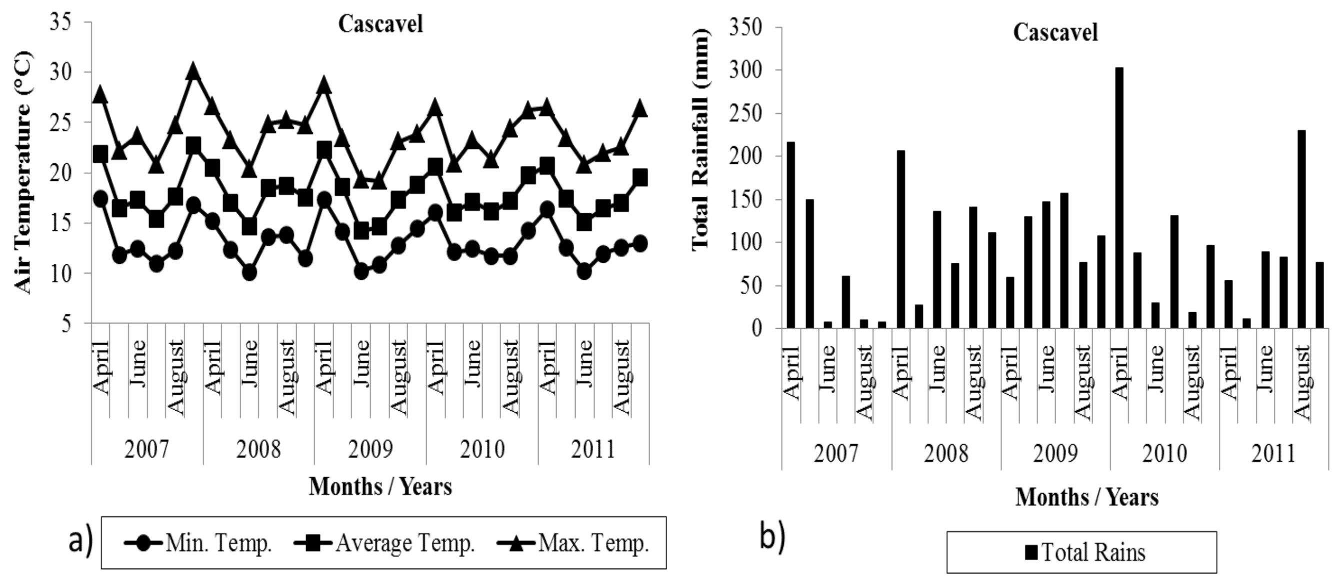

Figure 1. (a) Mean monthly minimum temperatures, maximum and average air (°C) in the months of April to September, between 2007 to 2011 (b) Total rainfall (mm) in the months of April to September from 2007 to 2011.

in June 2009, while September had the highest average air temperature (22.7°C) for the year 2007.

The total rainfall ranged from 8.4 mm for the months of June and September in 2007 and 302.8 mm in April 2010 (Figure 1b). The interaction of cultivars x sowing dates verified by analysis of the data was significant ($P<0.05$) only for the period from sowing to the silking, indicating different responses of cultivars in different sowing dates, in the harvests of 2007 to 2011.

The unfolding of the interaction of cultivars within each planting date was presented in Table 2.

The average number of days to cultivars reach silking in the three sowing dates was 71 days (Table 2). For the period of days between sowing and silking, there was an increase from 69 to 72 days between the cultivars sown in JD 115 and 145, respectively. The cultivar CD 124 had the highest number of days from sowing to the silking for the three sowing dates (April 25^{th}, May 15^{th} and 25^{th}), whose values were 74, 77 and 82 days, respectively. For cultivars sown in JD 145 (May 25^{th}), the average number of days from sowing to silking was 72 days.

The increase in the average number of days from sowing to silking (Table 2) for the seeded cultivars especially in the last sowing date DJ 145 (May 25^{th}), were possibly genetic characteristic of each cultivar, responding differently to environmental conditions especially related to low air temperature (Viganó et al., 2011). Since in this period according to the water balance performed to Rattlesnake in the years 2007 to 2011, by method of Thornthwaite and Mather (1955), water deficit was 5.7 mm in June 2007, down from 12.21 found mm by Oviedo et al. (2001) that causes damage to the wheat crop. Regression analysis of the data for the unfolding of

Table 2. Average duration of the period from sowing to silking (days) of thirteen wheat cultivars at three sowing dates, in the harvests from 2007 to 2011 in Cascavel, Brazil.

Cultivars	Sowing dates (Julian Days)			Average
	115	135	145	
CD 105	65^{C}	68^{B}	68^{D}	67
CD 113	62^{D}	66^{C}	68^{D}	65
CD 114	69^{B}	70^{A}	71^{C}	70
CD 115	71^{A}	72^{A}	74^{B}	72
CD 117	66^{C}	70^{A}	77^{B}	71
CD 118	71^{A}	72^{A}	72^{C}	72
CD 119	69^{B}	73^{A}	74^{B}	72
CD 120	67^{B}	71^{A}	72^{C}	70
CD 121	73^{A}	73^{A}	72^{C}	73
CD 122	73^{A}	72^{A}	71^{C}	72
CD 123	62^{D}	64^{C}	64^{D}	63
CD 124	74^{A}	77^{A}	82^{A}	78
ONIX	68^{B}	73^{A}	74^{B}	72
Average	69^{c}	71^{b}	72^{a}	
Average		71		
CV(%)		3.91		

Means followed by the same capital letter in the column and lowercase letter on the line belong to the same group, according to the grouping criteria of Scott and Knott (1974) at 5% probability. CV(%) = Coefficient of variation.

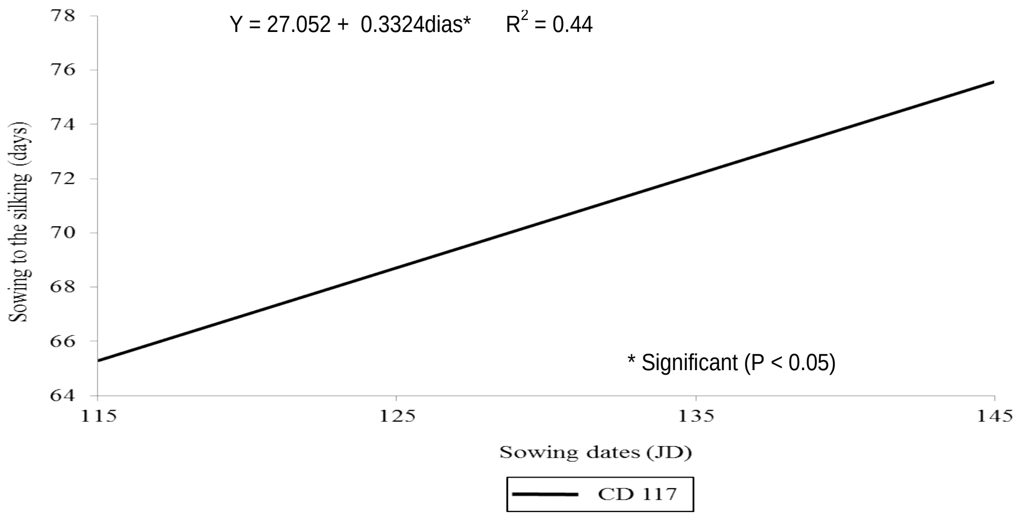

Figure 2. Average the period length of time from sowing to silking (days) for the cultivar CD 117 in three sowing dates, in the harvests from 2007 to 2011.

the interaction of cultivars x sowing dates, revealed a significant effect ($P<0.05$) only for the cultivar CD 117 in the period of days between sowing and the silking according to dates seeding increased linearly ($R^2 = 0.44$), as shown in Figure 2.

According to Figure 2 the regression analysis was significant only for the cultivar CD 117. Therefore, for this cultivar, sowing later result greater period of time between sowing and silking, in consequence of lower air temperatures was observed from May 25th (Figure 1a).

For variables, average period length of days from sowing to physiological maturity, silking to physiological maturity, growing degree-days sum to silking and to physiological maturity, growing degree-days sum degree-days from silking to physiological maturity, grain yield and hectoliter weight, no significant interaction ($P <0.05$) cultivar x sowing dates, carrying the analysis of the data with the average of the three sowing dates (Table 3).

The average duration from sowing to physiological maturity was 124 days, ranging from 120 (CD 123) and 127 days (CD117 and CD124). The growing degree-days sum average from seeding to physiological maturity was 1487 as can be seen in Table 3.

For cultivars CD 121, CD 122 and CD 124 the period between the SI-FM was 50 days, which resulted in growing degree-days sum for the period of 667, 663 and 696, respectively. This period was 57 days for cultivars CD 105, CD 117 and CD 123 resulting in growing degree-days sum of 749, 758 and 725, respectively (Table 3).

Table 3 reveals the reduction in the period from silking to physiological maturity for cultivars sown on May 25th, as well as period in which the cultivars were in the grain filling between the months of August to September. The average air temperature for five years in September was 19.7°C. One of the factors that may influence the length of grain filling is the increase in air temperature, which will increase the rate of grain filling and substantially reduce the length of time between silking and physiological maturity (Nedel et al., 1999).

The cultivars sowing on May 25th in Cascavel needed an average of 52 days between the SI-FM. The average growing degree-days sum from sowing to silking was 776. Among the evaluated cultivars, CD 124 had the highest accumulation of 834 degree-days (Table 3).

For grain yield there was no statistical difference between cultivars or sowing dates. The average yield was 3550 kg ha^{-1}. The hectoliter weight of the cultivars evaluated ranged from 73 kg hL^{-1} (CD 124) to 78 kg hL^{-1} (CD 122) (Table 3). The overall average was 76 kg hL^{-1}.

The Table 4 presented the correlation coefficients between the parameters evaluated using the average of the three sowing dates. The periods of the S-SI and SI-FM were the variables that showed a strong negative correlation (-0.60). A strong positive correlation was observed between the periods of S-FM and growing degree-days sum in this period (0.77) as shown in Table 4.

Grain yield showed significant positive correlation with the period of the SI-FM (0.29). For variable HW there is a significant negative correlation (-0.49) with the period of the S-SI. According to Table 4, increase in the number of days of the S-SI will decrease the period between the SI-FM and confirmed by significant negative correlation coefficient between periods, without altering the total number of days in the cycle, as can be seen in Tables 2 and 3.

The strong positive correlation between the periods of

Table 3. Average period of length sowing to physiological maturity (S-FM) and silking to physiological maturity (SI-FM), growing degree-days sum from sowing to silking (S-SI) and growing degree-days sum from sowing to physiological maturity (S-FM) and growing degree-days sum from silking to physiological maturity (SI-FM), grain yield (YIELD) and hectoliter weight (HW) of thirteen wheat cultivars, in the harvests from 2007 to 2011 in Cascavel, Brazil.

Cultivars	S-FM	SI-FM	Growing degree-days sum			Yield	HW
	(days)		S-SI	S-FM	SI-FM	(kg ha^{-1})	(kg hL^{-1})
CD105	124^B	57^A	741^C	1490^A	749^A	4005	76^A
CD113	121^B	56^A	718^D	1436^B	718^A	3742	76^A
CD114	122^B	52^B	774^B	1456^B	681^B	3765	77^A
CD115	126^A	54^A	804^A	1523^A	719^A	3074	74^B
CD117	127^A	57^A	777^B	1535^A	758^A	3545	76^A
CD118	126^A	54^A	796^A	1515^A	720^A	3341	76^A
CD119	126^A	55^A	796^A	1519^A	723^A	3507	77^A
CD120	123^B	53^B	773^B	1472^B	698^B	3488	77^A
CD121	123^B	50^B	807^A	1474^B	667^B	3577	76^A
CD122	122^B	50^B	800^A	1464^B	663^B	3575	78^A
CD123	120^B	57^A	700^D	1426^B	725^A	3422	76^A
CD124	127^A	50^B	834^A	1531^A	696^B	3560	73^B
ONIX	125^A	53^B	794^A	1494^A	700^B	3653	76^A
Date (JD)							
115	125^A	57^A	783^A	1487	704	3539	77^A
135	123^B	53^B	782^A	1489	707	3611	75^B
145	123^B	52^C	763^B	1484	721	3501	76^A
Average	124	54	776	1487	711	3550	76
CV (%)	2.87	9.20	5.14	3.41	8.59	17.15	3.19

Means followed by the same capital letter in the column and lowercase letter on the line belong to the same group, according to the grouping criteria of Scott and Knott (1974) at 5% probability. CV (%) = Coefficient of variation.

Table 4. Correlation coefficient of the length of periods (days), growing degree-day sum, grain yield (YIELD) and hectoliter weight (HW), in harvests from 2007 to 2011 in Cascavel.

Parameters		Length (days)		Growing degree-days sum			Yield	HW
		S-FM	SI-FM	S-SI	S-FM	SI-FM	(kg ha^{-1})	(kg hL^{-1})
Length (days)	S-SI	0.39**	-0.60**	0.71**	0.27*	-0.35**	-0.39**	-0.49**
	S-FM		0.50**	0.40**	0.77**	0.37**	-0.09^{ns}	-0.13^{ns}
	SI-FM			-0.32**	0.41**	0.66**	0.29*	0.35**
Growing degree-days sum	S-SI				0.38**	-0.50**	-0.16*	-0.45**
	S-FM					0.61**	-0.15*	0.02^{ns}
	SI-FM						-0.10^{ns}	0.40^{ns}
Yield								0.18*

^{ns} Not significant; * Significant at the 5% probability; ** Significant at 1% probability; (S-SI) period from sowing to the silking; (S-FM) period from sowing to physiological maturity; (SI-FM) period from sowing to physiological maturity.

S-FM and growing degree-days sum during this period was resulting time that culture remains in the field, growing higher value of degree-days sum if there is a greater number of days between sowing and maturity physiological (Table 4). The significant negative correlation between HW and S-SI suggested that an increase in the number of days of S-SI causes reduction in HW. The increase in the number of days of S-SI causes a reduction in the number of days in the period of the SI-FM, confirmed by the observed significant negative correlation for these variables. This results in reduced HW possibly by the decreasing number of days of the SI-FM, period that corresponds to grain filling as evidenced by the significant positive correlation of the variable HW with the period of the SI-FM (Table 4).

Conclusions

The results indicate that the average length of sowing to silking was 71 days. For the period from silking to physiological maturity the average length was 54 days.

The increase in length of time from sowing to silking in cultivars sown in May 25th (JD 145) was due to the decrease in air temperature.

The average of growing degree-days sum between the period from sowing to physiological maturity was 1487. The cultivars that stood out presenting a shorter period of silking to physiological maturity and high productivity were the cultivars CD 114, CD 120, CD 121, CD 122, CD 124 and Onix.

Conflict of Interest

The authors declared no conflict of interest.

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REFERENCRES

Abtrigo - Associação Brasileira da Indústria do Trigo (2006). História do trigo parte 2: A triticultura brasileira. Available on the Internet: <http://www.abitrigo.com.br/historia_ do_trigo2a.asp>. Accessed on March 6, 2013.

Brasil (1992). Ministério da Agricultura, Pecuária e Abastecimento e da Reforma Agrária. Secretaria Nacional de Defesa Agropecuária. Regras para análise de sementes. Brasília. P. 365.

Caviglione JH, Kiihl LRM, Caramori PH, Oliveira D (2000). Cartas climáticas do Paraná – edição 2000, versão 1.0. Londrina: Instituto Agronômico do Paraná. (versão em CD ROM).

Conab - Companhia Nacional de Abastecimento (2013a). Acompanhamento de safra brasileira: grãos, quinto levantamento, fevereiro 2013 / Companhia Nacional de Abastecimento. Brasília. P. 28.

Conab - Companhia Nacional de Abastecimento (2013b). Conjuntura semanal, Trigo – período de 31/12 a 04/01/2014. Available on the Internet: http://www. conab.gov.br/OlalaCMS/uploads/arquivos/13_01_09_11_50_23_conjuntura trigo3112a04012013.pdf. Accessed on May 6, 2014.

Coodetec - Cooperativa Central de Pesquisa Agrícola (2010). Informações técnicas para o trigo e triticale – safra 2011. Cascavel. P. 170.

Embrapa - Empresa Brasileira De Pesquisa Agropecuária (2006). Sistema brasileiro de classificação de solos. Rio de Janeiro. P. 306.

Ferolla SF, Vásquez HM, Silva JFC, Viana AP, Domingues FN, Aguiar RS (2007). Produção de matéria seca, composição da massa de forragem e relação lâmina foliar/caule + bainha de aveia-preta e triticale nos sistemas de corte e de pastejo. Revista Brasileira de Zootecnia. Brasília. 36:1512-1517. http://dx.doi.org/10.1590/S1516-35982007000700008

Ferreira DF (2011). Sisvar: a computer statistical analysis system. Ciência e Agrotecnologia. Lavras. 35:1039-1042. http://dx.doi.org/10.1590/S1413-70542011000600001

Nedel JL, Molas-Gonzalez CNE, Peske ST (1999). Variação e associação de características ligadas à formação do grão de genótipos de trigo. Scientia Agricola, Piracicaba. 56:1255-1260. http://dx.doi.org/10.1590/S0103-90161999000500029

Oliveira DM, Souza MA, Rocha VS, Assis JC (2011). Desempenho de genitores e populações segregantes de trigo sob estresse de calor. Bragantia, Campinas. 70:25-32. http://dx.doi.org/10.1590/S0006-87052011000100005

Oviedo AFP, Herz R, Rudorff BFT (2001). Efeito do estresse hídrico e da densidade de plantio no uso da radiação e produtividade da cultura do trigo (*Triticum aestivum* L.). Revista Biociência, Taubaté. 7:23-33.

Pimentel-Gomes F (2009). Curso de estatística experimental. Piracicaba. P. 451.

Scott A, Knott M (1974). Cluster-analysis method for grouping means in analysis of variance. Biometrics. Washington. 30:507-512.

Streck NA, Alberto CM (2006). Estudo numérico do impacto da mudança climática sobre o rendimento de trigo, soja e milho. Pesquisa Agropecuária Brasileira, Brasília. 41:1351-1359. http://dx.doi.org/10.1590/S0100-204X2006000900002

Thornthwaite CW, Mather JR (1955). The water balance. Centerton, N.J: Drexel Institute of Technology - Laboratory of Climatology. P. 104.

Viganó J, Braccini AL, Scapin CA, Franco FA, Schuster I, Moterle LM, Teixeira LR, Rocha R (2011). Efeito de anos e épocas de semeadura sobre o desempenho agronômico e rendimento de cultivares de trigo em Palotina, PR. Biosci. J. Uberlândia 27:259-270.

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Green corn grown in succession to pigeon pea fertilized with phosphorus sources and lime

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The practice of using green manure provides for the better utilization of chemical fertilizers and a lower cost of mineral fertilizers, and it promotes an increase in the soil's biological activity. Green house experiment was conducted to evaluate the effect of different phosphorus sources and lime on pigeon pea growth and their effects as green manures on the dry matter production of green corn. The experiment was conducted in a greenhouse of the Federal University of Mato Grosso, Rondonópolis campus, from May 2011 to May 2012. Two sources of phosphorus (rock phosphate and triple superphosphate) were used with and without liming. The treatments were assigned in completele randomised design (CRD) with twelve replicates, the treatments (contro), rock phoshate and triple super phoshate with and without liming formed the bases of the experiment. The phosphorus was incorporated into the soil with 200 mg dm^{-3} of phosphorus (P_2O_5) based on the availability of phosphate in the sources, that is, triple superphosphate (44% P_2O_5) and rock phosphate Bayóvar (29% P_2O_5) and the method of lifting the base saturation of 60%. The experiment was conducted in two phases: pigeon pea variety cv. BRS Mandarim was cultured in the first one, and the corn was variety cv. AG1051 grown in the soil under the residual effect of the first culture. Liming and rock phosphate provide a greater dry mass of pigeon pea leaves. In the presence of lime, triple superphosphate increased pigeon pea shoot and root dry weight. The cultivation of corn after pigeon pea fertilized with triple superphosphate and rock phosphate in the presence of lime, induced the dry matter production of corn.

Key words: Greeno fertilization, *Cajanus cajan*, rock phosphate, Triple superphosphate, Cerrado Oxisol.

INTRODUCTION

Phosphorus is the most limiting nutrient in biomass productivity (Corrêa et al., 2004). In Brazil, phosphorus deficiency is observed in most soils, as a result of the source material of low fertility, high acidity, low base saturation, toxicity of some chemical elements and the strong interaction of phosphorus with the soil

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(Lana, 1988; Raij, 1991; Moltocaro, 2007).

Phosphorus is the most limiting nutrient in biomass productivity (Corrêa et al., 2004). In Brazil, phosphorus deficiency is observed in several kids of soils, as a result of the source material of low natural fertility, high acidity, low base saturation, toxicity of some chemical elements and the strong interaction of phosphorus with the soil (Lana, 1988; Raij, 1991; Moltocaro, 2007).

The fixation process occurs when the phosphorus from fertilizers, once released into the soil solution, precipitates with aluminum (Al), iron (Fe), or calcium (Ca) or still is adsorbed to the surface of clay particles and oxides of Fe and Al. As a result of fixing the phosphor; it becomes part of compounds of low solubility, becoming less available for vegetal absorsion (Resende and Furtini Neto, 2007).

Natural phosphates simply result from the grinding of phosphate rock, which can then undergo physical processes to concentrate the product. The solubility of these fertilizers is variable and depends on the origin and degree of ionic and isomorphic substitutions. Some imported rock phosphates of sedimentary origin are more soluble than the Brazilian natural phosphates due to their lower crystallinity and higher reactivity in the soil; they are therefore called natural rock phosphate (Kaminski and Peruzzo, 1997). Sousa and Lobato (2003) observed a decrease in the solubility of rock phosphate with lime application, particularly in quantities above the amount recommended to raise the base saturation to a dose of 50%. This also reduces the costs associated with the practice of liming.

According to Abboud (1986), legumes are able to increase the utilization of nutrients provided by rocks through mechanisms such as soil acidification. The pigeon pea (*Cajanus cajan* (L.) Millspaugh) excretes specific compounds such as psídico acid, which complexes with iron and increases the availability of retained phosphorus for plants. Thus, the succession of different crops contributes to maintaining the balance of nutrients in the soil and to increasing fertility (Carvalho et al., 2004). Additionally, it provides a better utilization of chemical fertilizers and a lower cost of mineral fertilizer because it promotes increased soil biological activity (Hernani et al., 1995).

Therefore, the combined use of mineral fertilizers and green manure is a management practice that seeks to preserve the environmental quality without foregoing high crop yields (Arf et al., 1999). In this context, the objective was to evaluate the influence of fertilization with triple superphosphate and rock phosphate with or without liming, on pigeon pea growth and its effects as green manure on the dry matter production of green corn.

MATERIAL AND METHODS

The experiment was conducted in a greenhouse of the Federal University of Mato Grosso, Rondonópolis campus, which has the geographic coordinates 16° 28 '17'' South, 54° 28' 17'' West, an altitude of 284 m and an tropical climate with dry winter season, Köppen, from May 2011 to May 2012.

The treatments were replicated twelve times and laid out in completele randomised design (CRD). Two phosphorus sources (triple superphosphate (TSP) and rock phosphate – Bayóvar) were used. The treatments were arranged in a 3 × 2 factorial design. Pigeon pea was fertilized with rock phosphate and TSP with and without liming. In total, there were 72 experimental units represented by 7 dm^3 plastic pots.

The experiment was conducted in two phases: The bean crop pigeon pea cv. BRS Mandarin was sown in the first one, and corn cv. AG1051 was cultured under the residual effect of the first crop. Oxisol (Embrapa, 2006) was used in this experiment. The contents of the 0 to 0.20 m layer were pH ($CaCl_2$) = 4.1; Al = 1.1 cmol c dm^{-3}, Ca 0.3 = cmol c dm^{-3}, Mg = 0.2 cmol c dm^{-3}, P-Mehlich = 2.4 mg dm^{-3}, K = 28 mg dm^{-3}, S = 6.8 mg dm^{-3}, MO = 22.7 g dm^{-3}, V = 9.8% Clay = 367 g kg^{-1}, Sand = 549 g kg^{-1} and Silt = 840 g kg^{-1}, according to the methodology of Embrapa (1997).

According to the results of chemical analysis, the calculation for the correction of soil acidity was carried out, treatments for triple superphosphate, rock phosphate and without fertilizer that were associated with the presence of lime, using the method for lifting base saturation to 60%. After 30 days of incubation of the sinter was determined; the pH of the soil showed the following values: 5.30, 5.19 and 5.19 for triple superphosphate, rock phosphate and no phosphate fertilizer, respectively. Throughout the experimental period, the soil moisture in the experimental units was maintained at 60% of the maximum water holding capacity using a gravimetric method.

Phosphorus was incorporated into the soil with 200 mg dm^{-3} of phosphorus (P_2O_5) based on the availability of phosphate in the sources, that is, triple superphosphate (44% P_2O_5) and rock phosphate Bayóvar (29% P_2O_5).

After the phosphorus was conducted by sowing 20 seeds of pigeon pea per experimental unit at a depth of two inches. Thinning was performed on the tenth day after sowing, leaving five plants per experimental unit.

A micronutrient fertilizer was applied using a solution containing 1 mg dm^{-3} B and Cu, 3 mg dm^{-3} Mn and Zn 0.2 mg dm^{-3} of Mo, and the following sources: H_3BO_3, $CuCl_2.2H_2O$, $CaSO_4.2H_2O$, $ZnCl_2$ and MoO_3. The fertilization with macronutrient was added using potassium (80 mg dm^{-3}) and sulfur (10 mg dm^{-3}) was performed after 14 days from sowing using KCl and $CaSO_4$ as sources, respectively.

The cultivation period for the pigeon pea was 107 days; after which the plants were cut at ground level. A 2-mm sieve was used to separate the roots, and the soil was returned to the vessels of the respective treatments. Then, plant material was placed in paper bags and subjected to an oven with forced air circulation at ± 65°C until a constant dry mass of the dry weight of shoots (leaf and stem) and roots was obtained.

After weighing, the dry shoots and roots of the pigeon pea was ground in a Willey mill and sieved to 2 mm. It was then blended with the sieved soil after cultivating the pigeon pea in their respective treatments and incubated for 90 days.

After the incubation period of the dry mass of pigeon pea in ground corn, seeding was conducted using 7 seeds per experimental unit at a depth of 5 cm. Thinning was performed at 12 days after sowing, leaving two plants in each experimental unit

After 60 days of sowing, cutting the corn plants close to the ground surface was conducted. The corn roots were separated from the soil using sieves with 4 mm mesh. All the plant material was packaged in paper bags, identified and dried in an oven with forced air circulation at a temperature of ±65°C until a constant mass was obtained. The samples were subsequently weighed on a precision scale to determine the dry weight of shoot and root.

Data were subjected to analysis of variance, using F tests and

Table 1. Dry mass pigeon pea leaves, stems and root fertilized with phosphorus sources and liming in the Cerrado Oxisol.

Phosphorus source		**Triple superphosphate**	**Rock phosphate**	**Control treatment**
			Dry mass of leaves (g pot^{-1})	
		22.98^{b}	25.21^{a}	9.95^{c}
Liming		Presence		Absence
			Dry mass of leaves (g pot^{-1})	
		22.19a		16.57^{b}
CV%			13.72	
		Dry mass stems (g pot^{-1})		
Liming	Presence	34.80^{aA}	34.46^{aA}	19.90^{bA}
	Absence	26.72^{aB}	27.97^{aB}	6.75^{bB}
CV%			10.13	
		Dry mass root (g pot^{-1})		
Liming	Presence	28.40^{aA}	24.29^{bA}	15.84^{cA}
	Absence	24.20^{aB}	21.52^{aA}	6.40^{bB}
CV%			17.14	

Means followed by the same letter within a row compare fertilization within the liming interaction and do not differ by Tukey's test ($P \leq 0.05$). Means followed by the same uppercase letter within a column compare liming and fertilization interaction and do not differ by Tukey's test ($P \leq 0.05$). Means followed by the same letter within a row compare fertilization within the liming interaction and do not differ by Tukey's test ($P \leq 0.05$). Means followed by the same uppercase letter within a column compare liming and fertilization interaction and do not differ by Tukey's test ($P \leq 0.05$).

Tukey's test at 5% probability with the statistical program SISVAR (Ferreira, 2008).

RESULTS AND DISCUSSION

The response of pigeon pea to phosphorus, as measured by the dry mass of leaves, showed no significant interaction in terms of sources or liming (Table 1). Through fertilization with rock phosphate and triple superphosphate observed increase of 15.26 and 13.03 g pot^{-1} dry weight of leaves of pigeon pea when compared with the absence of phosphate fertilizer. This reflects the influence of natural scarcity of phosphorus in the development of pigeon pea in soils of Cerrado.

The rock phosphate Bayóvar surpassed triple superphosphate in terms of its effect on the dry mass of pigeon pea leaves. This response indicates that the use of rock phosphate was an effective alternative to a phosphorus supply for pigeon pea, surpassing even a source with high solubility.

Phosphorus deficiency may decrease the leaf area of plants primarily by reducing the number of leaves and secondarily by limiting the expansion of the leaf (Lynch et al., 1991; Rodríguez et al., 1998).

Over two cropping cycles, Kaminski and Peruzzo (1997) observed that the sums of crop production provided by the natural reactive Gafsa Phosphates and Arad were almost equal to that provided by superphosphate.

In the presence of lime, the dry mass of pigeon pea leaves was higher (5.62 g pot^{-1}) than that of the specimen raised in the absence of liming. These results were corroborated by Novaes et al. (1988), who reported that in acid soils, pigeon pea responds very well to the addition of lime incorporated into the soil.

The low availability of phosphorus in the soil of the present study provided a high response from the practice of liming, since, according to Vidor and Freire (1972), Silva et al. (1994) and Ernani et al. (2000), the absence or low response to liming have been checked for plant species especially in soils where the availability of phosphorus in the soil is high.

For the stem dry weight, there was a significant relationship between the sources of phosphorus and liming (Table 1). In the presence of lime, reactive rock phosphate and triple superphosphate equaled and promoted dry matter production superior to other treatments. These results show the importance of liming and phosphate fertilization because this process neutralizes soil acidity and the toxic effects of aluminum and manganese while also promoting, according to Paauw (1965), a decrease in the retained surface anions, particularly phosphates.

Upon assessing the root dry weight of the pigeon pea, it was found that there was a significant interaction between the sources of phosphorus and liming (Table 1). In the presence of lime, triple superphosphate increased the dry root mass. The solubility characteristics of phosphorus

Table 2. Dry corn shoot and root mass in the continuous crop of pigeon pea fertilized with phosphorus sources and liming in the Cerrado Oxisol.

Phosphorus source		Triple superphosphate	Rock phosphate	Control treatment
		Dry mass shoot (g pot^{-1})		
Liming	Presence	23.71^{aA}	24.56^{aA}	10.14^{bA}
	Absence	17.87^{aB}	15.83^{aB}	2.03^{bB}
CV%			12.5	

Phosphorus source		Triple superphosphate	Rock phosphate	Control treatment
		Dry mass root (g pot^{-1})		
Liming	Presence	21.62^{aA}	19.45^{aA}	9.71^{bA}
	Absence	13.09^{aB}	10.18^{aB}	2.00^{bB}
CV%			18.16	

Means followed by the same letter within a row compare fertilization within the liming interaction and do not differ by Tukey's test ($P \leq 0.05$). Means followed by the same uppercase letter within a column compare liming and fertilization interaction and do not differ by Tukey's test ($P \leq 0.05$).

sources are of great importance in relation to their efficiency. The phosphates of higher solubility are more readily available and favor the uptake and utilization of nutrients, particularly for short cycle crops (Novais and Smyth, 1999). However, in terms of weight, the rock phosphate was equal to the triple superphosphate in the absence of liming.

According to Rheinheimer et al. (2001), liming is needed, but the high pH slows the dissolution of rock phosphate and reduces the availability of phosphorus from this fertilizer to plants, particularly above pH 5.2. Thus, Khasawneh and Doll (1978) recommended the application of low solubility phosphates before liming to enable its dissolution by the action of hydrogen ions. A subsequent liming would correct the detrimental effects of soil acidity (Kliemann, 1995).

An important feature for the use of rock phosphate is the type of implanted culture. Generally, legumes are higher in calcium requirements and have the ability to acidify the rhizosphere; they are thus more efficient in the utilization of phosphorus from rock phosphate (Novais and Smyth, 1999).

Kliemann (1995) evaluated the effects of liming and phosphorus sources on the yield of soybean in two soils of Cerrado Oxisol. In their study, the researchers assessed the dark loam, with virtually no toxic aluminum, and observed that the effects of liming were not very pronounced in either the immediate or the residual plants.

According to Pott et al. (2007), the pigeon pea is a legume that exhibits the greater absorption of phosphorus because organic acids are exuded by the roots. As a result, pigeon peas are able to act as potentiating and solubilizing sparingly soluble phosphorus sources, similar to natural phosphates.

After assessing the incubation period of the plant residue of pigeon pea and its influence on the growth of corn, a significant effect on the dry matter corn was observed (Tables 2). The residual effect of pigeon pea fertilized with triple superphosphate and rock phosphate in the presence of lime provided higher yields of dry mass of shoots and roots of corn.

Comparing treatments in the presence or absence of liming, there was an increase in the shoot dry weight of 5.84; 8.73 g and 8.11 g pot^{-1} and root 8.53; 9.27 and 7.71 g pot^{-1} with triple superphosphate and rock phosphate treatment without phosphorus fertilization.

The importance of setting the initial growth of green corn was already evident in the first weeks of study because in the absence of liming, plant growth was markedly reduced. Alcântara et al. (2000) observed higher values in soils under pigeon pea and crude fertilization. According to the authors, these higher values were due to the increased capacity of these pulses to return calcium and magnesium to the soil via their biomass.

Ribeiro (1996) studied the effects of the incubation of green manures, velvet bean (*Mucuna aterrima*) and kudzu (*Pueraria lobata*), as well as their effects on the production of rice. At the end of the beneficial effects of the legumes, that is, 180 days after incubation, no differences in the dry matter production of the crop were observed between treatments with the legume and the control (without incubation). The same phenomenon was not observed in the present study, which showed that pigeon pea fertilized with triple superphosphate and rock phosphate in the presence of lime, followed by an incubation period of 90 days, significantly increased the production of the dry mass of corn shoots and roots.

Aita and Giacomini (2003) found that legumes were rapidly decomposed after management, resulting in asynchrony between the release of nitrogen from the crop residues and their demand for corn in succession.

Legumes in general have the ability to fix atmospheric nitrogen (N_2) in symbiosis with rhizobium and a low carbon/nitrogen (C/N) ratio, which favors the rapid decomposition and release of this nutrient to the successor cultures (Ceretta et al., 1994). Moreover, it must be considered that the addition of organic matter through green manure results in general changes in the physical, chemical and biological soil properties (De-Polli and Chada, 1989; Tanaka et al., 1992), thereby increasing the production cultures.

Conclusions

In general, liming and rock phosphate provide a greater dry mass of leaves of pigeon pea. Superphosphate provides an increased dry mass of stems and roots of pigeon pea in the presence of lime.

The effects of pigeon pea as a green manure which subjected to fertilization with triple superphosphate and rock phosphate in the presence of lime increase dry matter production of corn in continuous cultivation.

REFERENCES

Abboud ACS (1986). Eficiência da adubação verde associada a fosfato natural de Patos de Minas. Dissertação (Mestrado) - Universidade Federal Rural do Rio de Janeiro, Seropédica, RJ. P. 320.

Aita C, Giacomini JS (2003). Decomposição e liberação de nitrogênio de resíduos culturais de plantas de cobertura de solo solteiras e consorciadas. Rev. Bras. Ciênc. Solo 27(4):601-612. http://dx.doi.org/10.1590/S0100-06832003000400004

Alcântara FA, Furtini Neto AE, Paula MBP, Mesquita JA (2000). Adubação verde na recuperação da fertilidade de um Latossolo Vermelho- escuro degradado. Pesq. Agropec. Bras. 35(2):227-288. http://dx.doi.org/10.1590/S0100-204X2000000200006

Arf O, Silva LS, Buzetti S, Alves MC, Sá ME, Rodrigues RAF, Hernandez FBT (1999). Efeitos na cultura do trigo da rotação com milho e adubos verdes, na presença e na ausência de adubação nitrogenada. Bragantia 58(2):323-334. http://dx.doi.org/10.1590/S0006-87051999000200012

Carvalho MAC, Athayde MLF, Soratto RP, Alves MC, Arf O (2004). Soja em sucessão a adubos verdes no sistema de plantio direto e convencional em solo de Cerrado. Pesq. Agropec. Bras. 39(11):1141-1148.

Ceretta CA, Aita C, Braida JA, Pavinato A, Salet RL (1994). Fornecimento de nitrogênio por leguminosas para o milho em sucessão nos sistemas de cultivo mínimo e convencional. Rev. Bras. Ciênc. Solo 18:215-220.

Corrêa JC, Mauad M, Rosolem CA (2004). Fósforo no solo e desenvolvimento de soja influenciados pela adubação fosfatada e cobertura vegetal. Pesq. Agropec. Bras. 39(12):1231-1237.

De-Polli H, Chada SS (1989). Adubação verde incorporada ou em cobertura na produção de milho em solo de baixo potencial de produtividade. Rev. Bras. Ciênc. Solo 13:287-293. http://dx.doi.org/10.1590/S0100-204X2004000100007

EMBRAPA - Empresa Brasileira de Pesquisa Agropecuária (1997). Manual de métodos de análise de solo. Serviço Nacional de Levantamento e Conservação de Solos. 2 ed., Rio de Janeiro, P. 212.

EMBRAPA- Empresa Brasileira de Pesquisa Agropecuária (2006). Sistema brasileiro de classificação de solos. Centro Nacional de Pesquisa de Solos. Rio de Janeiro. P. 306.

Ernani PR, Nascimento JAL, Campos ML, Camillo RJ (2000). Influência da combinação de fósforo e calcário no rendimento de milho. Rev. Bras. Ciênc. Solo 24(3):537-544. http://dx.doi.org/10.1590/S0100-06832000000300007

Ferreira DF (2008). SISVAR: um programa para análises e ensino de estatística. Rev. Sympos. 6:36-41.

Hernani LC, Endres VC, Pitol C, Salton JC (1995). Adubos verdes de outono/inverno no Mato Grosso do Sul. Dourados: Embrapa-CPAO, P. 93.

Kaminski J, Peruzzo G (1997). Eficácia de fosfatos naturais reativos em sistemas de cultivo. Núcleo Regional da Sociedade Brasileira de Ciência do Solo, Boletim Técnico 3:31.

Khasawneh FE, Doll EC (1978). The use of phosphate rock for direct application to soils. Adv. Agron. 30:159-165. http://dx.doi.org/10.1016/S0065-2113(08)60706-3

Kliemann HJ (1995). Efeitos da calagem e de fontes de fósforo no rendimento da soja em 2 solos de Cerrado. Anais Escola Agronomia e Veterinária 25(2):129-139.

Lana RMQ (1988). Fontes, doses e profundidade de aplicação do fósforo na cultura do feijão (*Phaseolus vulgaris* (L.). Viçosa, UFV, P. 136.

Lynch J, Läuchli A, Epstein E (1991). Vegetative growth of the common bean in response to phosphorus nutrition. Crop Sci. 31(2):b380-387. http://10.2135/cropsci1991.0011183X003100020031x

Moltocaro RCR (2007). Guandu e micorriza no aproveitamento do fosfato natural pelo arroz em condições da casa-de-vegetação. 65p. Dissertação (Agricultura Tropical e Subtropical) – Instituto Agronômico IAC, Campinas.

Novaes NJ, Vitti GC, Manzano A, Esteves SN, Girotto CR (1988). Efeito da fosfatagem, calagem e gessagem na cultura do guandu. I. Produção de matéria seca e proteína, e teores de proteína e fibra. Pesq. Agropec. Bras. 23(9):1049-1054.

Novais RF, Smyth TJ (1999). Fósforo em solo e planta em condições tropicais. Viçosa, MG: Universidade Federal de Viçosa, P.399.

Paauw F (1965). Factors controlling the efficiency of rock phosphate for potatoes and rye on humic sandy soils. Plant Soil 22(1):81-98. http://dx.doi.org/10.1007/BF01377691

Pott CA, Muller MML, Bertelli PB (2007). Adubação verde como alternativa agroecológica para recuperação da fertilidade do solo. Ambiência 3(1):51-63.

Raij B (1991). Fertilidade do solo e adubação. Piracicaba: Potafos, P. 343.

Resende AV, Furtini Neto AE (2007). Aspectos relacionados ao manejo da adubação fosfatada em solos do Cerrado. Planaltina, DF: Embrapa Cerrados, 30 p. (Embrapa Cerrados. Documentos, 195).

Rheinheimer DS, Gatiboni LC, Kaminski J (2001). Mitos e verdades sobre o uso de fosfatos naturais na Agroecologia. Santa Maria: UFSM (Universidade Federal de Santa Maria), Nota Técnica 1.

Ribeiro GA (1996). Efeito de períodos de incubação de adubos verdes (mucuna e puerária) na liberação de nitrogênio (15N) e enxofre (35S) para o arroz. Piracicaba: ESALQ, Dissertação de Mestrado. P. 82.

Rodríguez D, Keltjens WG, Goudriaan J (1998). Plant leaf area expansion and assimilate production in wheat (*Triticum aestivum* L.) growing under low phosphorus conditions. Plant Soil 200:227-240. http://dx.doi.org/10.1023/A:1004310217694

Silva LHB, Miranda CC, Miranda LN (1994). Efeito da micorriza vesiculo arbuscular no crescimento de variedades de trigo sensível e tolerante ao alumínio, em solo de cerrado. Rev. Bras. Ciênc. Solo 18:407-414.

Sousa DMG, Lobato E (2003). Adubação fosfatada em solos da região do Cerrado. Piracicaba: Potafos, Informações Agronômicas 102:16.

Tanaka RT, Mascarenhas HAA, Dias OS, Campidelli C, Bulisani EA (1992). Cultivo da soja após incorporação de adubo verde e orgânico. Pesq. Agropec. Bras. 27:1477-1483.

Vidor C, Freire JRJ (1972). Efeito da calagem e da adubação fosfatada sobre a fixação simbiótica do nitrogênio pela soja (*Glycine max* (L.) Merrill). Agronomia Sulriograndense 7:181-190.

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Carbon and nitrogen stocks under different management systems in the Paraiban "Sertão"

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The change in land use leads to significant changes in carbon (C) and nitrogen (N) stocks in the soil and consequently in the global cycle of these elements. The purpose of this study was to evaluate C and N stocks in soils under different management systems in the Paraiban "Sertão". This study was carried out in the watershed of Val Paraiso stream, State of Paraiba, Brazil. The climate is warm tropical with severe drought, reaching over 35°C in times of higher temperatures. The vegetation is basically composed of Caatinga Hiperxerófila and the predominant soil in this area is classified as Vertisol. The following systems treatments were tested: native vegetation, sparse vegetation, pasture, annual and permanent agriculture. Soil sampling was performed in four respective sites (four profiles). Samples were stratified in four layers: 0-10, 10-20, 20-30 and 30-40 cm. Soil attributes determined and calculated were: bulk density, organic C and N contents, and C and N stocks. The lower values of bulk density were presented in the area of native vegetation and in 0-10 cm soil layer, compared to other management systems and layers. The implementation of agricultural systems in areas that had native vegetation decreased the C and N contents and stocks, in the same way, these values decreased relative soil layers analyzed. The agricultural production and livestock systems are functioning as CO_2-C emitter when compared with the native vegetation.

Key words: Native vegetation, sparse vegetation, pasture, annual agriculture and permanent agriculture.

INTRODUCTION

With the transformation of natural ecosystems into agricultural systems, complex and stable biological systems are replaced by simple and unstable systems. This modification in the land use leads to change in soil organic components stocks by altering the addition and decomposition rates of organic matter. Thus, the balance of the carbon (C) and nitrogen (N) cycles is changed, and C inputs become lower, which leads to the reduction of the quantity and modification of soil organic matter quality (Boddey et al., 2012).

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When deploying agricultural systems, the soil organic carbon stocks may suffer reductions of 20 to 50%, depending on depth. In tropical regions this process occurs faster due to climate conditions that cause intense microbial activity, accelerating the decomposition of organic residue that is deposited on the soil.

In farming areas, soil disturbance by cultivation practices (plowing, harrowing) improves the porosity of the soil and thus accelerates the oxidation of organic matter causing mineralization thereof. This can result in a negative difference between the uptake and loss of organic matter. However, farming systems subjected to an appropriate management practice reduce erosion and tend to present increase in organic matter in the soil surface (Portugal et al., 2008).

In the Brazilian semi-arid tropics, the conventional agriculture contributes to the increase of degraded areas, thus causing increased losses of nutrients and organic matter in soils (Nogueira et al., 2008). The human intervention has led to a process of environmental degradation in the region by the uncontrolled use of this environment.

Estimates of C and N stocks in Brazilian semi-arid tropics, mainly in the biome Caatinga, where the research was conducted, are few and are faced with the lack of information available on the soil's organic C and N contents under different land uses. Inadequate management of natural resources for exploration of Caatinga biome as extensive cattle, vegetation over-grazing, predatory extractivism, replacement of native vegetation by crops, clearing new area for planting using fire are some of the degradation of this ecosystem (Giongo et al., 2011).

According to Silva (2000), a great proportion of semi-arid soils, about 82% of the area, where the Paraiba Sertão is included, present low productivity potential due to poor nutrient content, soil profile depth, deficient drainage, low organic matter content and high exchangeable N concentration.

Several researchers have evaluated and assessed the effects of replacement of native vegetation by crops in relation to the carbon stock. To exemplify, Fracetto et al. (2012) found that the areas under natural vegetation promoted the maintenance of C (90 Mg ha^{-1}) and N (10 Mg ha^{-1}) stocks for the 0 to 30 cm layer. The change of land use for the castor (*Ricinus communis* L.) cultivation caused decreases of approximately 50% in soil C and N stocks in relation to the reference area in the first ten years of the adopted crop. To assess the potential of the impact of different land uses on the issue of C emissions and / or increase of C and N stocks is necessary to effectively quantify these changes in relation to a reference management, such as the soil, under native vegetation (Giongo et al., 2011). The objective of this study was to evaluate changes in carbon and nitrogen contents and stocks under different land use in Paraiba"Sertão.

MATERIALS AND METHODS

The study area is located in the watershed of Val Paraiso stream, inserted in the Northwest portion of Paraíba State, Brazil (6°37'54" to 6°44'29" S and 38° 18'21" to 38°24'12" W). According to the Koppen classification, climate is warm tropical with severe drought, reaching over 35°C in times of higher temperatures. The vegetation is basically composed of Caatinga Hiperxerófila and the predominant soil in the Val Paraiso watershed is classified as Vertisol (FAO, 1990).

In the watershed, five management systems were identified: native vegetation, taken as reference (area covered by arboreal natural vegetation); sparse vegetation (area covered by natural vegetation typical of the Caatinga), pasture (area covered by sparse vegetation and planted); annual crops (areas of temporary crops, for example, corn and beans cultivation) and permanent agriculture (crop with high vegetation cover, mainly composed of permanent crops, for exemple, guava, coconut palm, cactus pear, mango and papaya).

For each management systems were opened four soil profiles occurring in the same soil class. In each profile, the soil samples were collected from July to August 2012, at layers of 0-10, 10-20, 20-30 and 30-40 cm, using auger. Two simple undisturbed samples were collected in all layers by the volumetric ring method using a stainless steel cylinder of 90.21 cm^3 for determination of bulk density; each constituting a repetition. In addition, at each layer was collected one single sample deformed. These samples, after being air-dried and passed through a 2 mm sieve, were characterized chemically according to the methods recommended by Embrapa (1997).

Walkley-Black method (Black et al., 1965) was used to determine the soil organic carbon (SOC). The carbon stock was calculated at layers of 0-10, 10-20, 20-30 and 30-40 cm, from the expression:

$$CStock=(OC\times Ds\times e)/10 \quad (1)$$

where CStock is the stock of organic carbon in the layer (Mg ha^{-1}), OC is the concentration of total organic carbon (g kg^{-1}), Ds is the soil bulk density of the average layer of the soil (kg dm^{-3}), "e" is considered the layer thickness (cm). The nitrogen stock was calculated in a similar way to carbon stock, having used the expression:

$$NStock=(Nt x Ds x e) \quad (2)$$

where NStock is the stock of total nitrogen in certain depth (Mg ha^{-1}) and Nt is the total N content (dag kg^{-1}).

To compare in different management situations of the sampling areas that showed significantly different values in soil bulk density, the soil C and N stock was corrected by a fixed mass, that is, considering a soil density of 1 g cm^{-3} following the calculations presented by Sisti et al. (2004).

$$S_c=\sum_{n-i}S+\{[M_{ai}-(\sum_n M_a-\sum_n M_r)]Q_i\} \quad (3)$$

where S_c is the corrected C stock by the soil mass (Mg ha^{-1}); $\sum_{n-i}$ S is the sum of the C stocks of layers without the last sampled layers; M_{ai} is the soil mass of the last layer of soil sampled; ($\sum_n M_a$ is the sum of the total mass of sampled soil; $\sum_n M_r$ is the sum of the mass of soil reference, and Q_i is the C content in the last layer sampled.

To check the tendency to accumulate or lose organic C in relation to the reference system (native vegetation), the variation of the C stock was calculated in relation to native vegetation (Δ CStock, Mg ha^{-1}) as the difference between the mean values of carbon stock in this system and in each other, in the layers studied.

The experimental design was completely randomized in factorial scheme 4 x 5, with four replicates (four profiles), that is, four layers (0-10; 10-20; 20-30 and 30-40 cm) and five management systems

Table 1. Analysis of variance summary for the soil chemical attributes.

Source of variation	DF	Mean square				
		Ds	OC	TN	CStock	NStock
Local	4	0.29**	20.15**	0.002**	19.06*	0.20*
Res.(a)	15	0.03	1.86	0.0002	6.55	0.07
Layer	3	0.16**	36.78**	0.004**	51.95**	0.53**
Layer x Local	12	0. 009	4.34**	0.0005**	9.71**	0.10**
Res.(b)	45	0.02	1.26	0.0001	3.68	0.04

*, ** Significant at 5 and 1% (F test), respectively; Local = areas of management systems; Res = residue; Ds= soil bulk density; OC= organic carbon; TN= total nitrogen; CStock= carbon stocks; NStock = nitrogen.

Table 2. Soil bulk density of the management systems as a function of depth and means of all layers and of all management systems.

Depth (cm)	Management systems					
	Native vegetation	Sparse vegetation	Pasture	Annual crops	Permanent agriculture	Means
0-10	1.34	1.53	1.43	1.73	1.50	1.51 c
10-20	1.32	1.59	1.53	1.78	1.61	1.57 bc
20-30	1.49	1.60	1.57	1.84	1.71	1.64 ab
30-40	1.65	1.66	1.91	1.86	1.74	1.72 a
Means	1.45 c	1.60 bc	1.55 bc	1.81 a	1.64 ab	

Means followed by same letters in the rows and columns do not differ as function of management systems and as function of depth, respectively, by Tukey test to 5% probability.

(native vegetation, sparse vegetation, pastures, annual crops and permanent agriculture).The analyses of variance (ANOVA) and Tukey test at 5% probability were made for comparison of means of the results, according to Ferreira (2000).

RESULTS AND DISCUSSION

The bulk density (BD), organic carbon (OC), nitrogen (N), carbon stocks (CStocks) and nitrogen stocks (NStocks) values, analyzed statistically presented significant differences in relation to management systems (local) and depths. For these attributes, with the exception of soil bulk density, there was also significant difference in relation to the Local X Layers interaction (Table 1).

According to the use of the soil, the BD values of agricultural systems were higher than Ds under native vegetation (Table 2). This demonstrates that systems with low and / or absence of soil management practices are had the best physical conditions of the soil preventing the compaction process of the same. Likewise, the larger amount of organic carbon in the natural vegetation system favors the soil porosity and consequently lower values of the same density. This behavior is similar to that reported by Lima et al. (2011) that found lower density values for native vegetation system compared to conventional soil cultivation system in the semi-arid region of Piauí. Similar results were found by Colonego et al. (2012) and Guareschi et al. (2012).

The native vegetation (NV) presented the lowest mean values of soil BD, probably due to other management systems which have suffered mechanical pressures in soils (harrowing, seeding, fertilization, machine traffic) and animal trampling. The average soil BD values increased with increasing depth (Table 2) supporting Coutinho et al. (2010), who observed that the forest, grassland and eucalyptus plantations systems increased values of soil bulk density from the soil surface up to a depth of 60 cm. The lowest Ds value of topsoil occurred due to increased input of organic matter in this layer compared with the other subsurface corroborating Bernardi et al. (2007), who found in the environment Caatinga, increased values of bulk density with increasing depth.

Generally the higher the density values, the higher the degree of soil compaction thereby causing negative effects on root penetration, water infiltration and soil aeration, storage and availability of water for plants. In the present study, the Ds values for all management systems were higher than the density of 1.27 g cm^{-3}, including, in some cases, over the range of 1.27 and 1.57 g cm^{-3} which, according to Corsini and Ferraudo (1999) is restrictive to root growth and water infiltration into the soil. The soil OC contents under vegetation native were higher than those found in soils under permanent agriculture, pasture and annual crops systems and only in the permanent agriculture system there was no significant

Table 3. Average contents of organic carbon (g kg^{-1}) of the management systems as a function of depth

Depth (cm)	Management systems				
	Native vegetation	Sparse vegetation	Pasture	Annual crops	Permanent agriculture
0-10	11.10 ^{aA}	8.83 ^{aAB}	7.68 ^{aBC}	6.95 ^{aBC}	6.05 ^{aC}
10-20	9.10 ^{aA}	5.88 ^{baB}	5.60 ^{abB}	4.80 ^{bB}	5.18 ^{aB}
20-30	6.23 ^{bA}	5.00 ^{bA}	4.35 ^{bA}	6.00 ^{abA}	5.15 ^{aA}
30-40	6.18 ^{bA}	4.45 ^{bA}	5.18 ^{bA}	3.95 ^{bA}	6.03 ^{aA}

Means followed by the same lowercase letters in columns and uppercase letters in the lines do not differ by Tukey test to 5% probability.

difference in OC with depth (Table 3). Probably, this is because farmers, after the installation of permanent crops, do not care about organic fertilizer and / or soil management.

In the others systems (native vegetation (NV), sparse vegetation (SV), pasture (P), annual crops (AC)), due the greater amount of organic material on the soil surface, from the fall of leaves, twigs and bark of trees in the forest, forming the organic litter and higher density of fine roots, the OC decreased with increasing depth. This fact was observed in research of Vasconcelos et al. (2010) and Campanha et al. (2009) that evaluated soil carbon under natural vegetation, agroforestry and traditional cultivation.

Nunes et al. (2009) found values of total OC of 18.72 and 1.86 g kg^{-1} for forest and conventional tillage, respectively. According to Oliveira et al. (2008), the fact that agricultural systems have shown lower C contents and irregularity in the reduction of the carbon in the subsurface layers probably occurred due to soil tillage management in these systems.

Evaluating soil OC contents in the topsoil (0-10 cm) of different tillage systems, we observed that there was a reduction in relation to NV, of 20, 31, 37 and 45% for SV, P, AC and PA, respectively. Maia et al. (2006) evaluating the impact of four agroforestry system and conventional systems on soil quality, in Sobral - CE, (Caatinga biome: highly fragile, soil degradation, low soil fertility, high organic matter decomposition rates, high soil erosion, limited water availability and sporadic precipitation greatly limit agricultural production) found a reduction in the carbon content in the order of 40.3, 38.4 and 35% for treatments that have intensive cultivation of the soil, agro-silvopastoral system and traditional culture, respectively, in the 0-6 cm layer, compared to native forest.

This reduction in OC with agricultural land use is similar to that observed by Fracetto et al. (2012) that found higher values of C and N in the natural environment Caatinga in all layers sampled; likewise the C and N contents decreased with increasing depth. This situation was expected and typical of native vegetation environment in order that the greatest input of plant residues on the soil surface allows a slow and gradual decomposition of soil organic matter.

According to Stevenson (1982), the reduction of the input of soil OC should not be only reduction of the amount of residue added, but also to increased microbial activity caused by better aeration conditions, higher temperatures and more frequent alternation of wetting and drying of the soil, by the continued use of implements, by fires, and losses caused by erosion.

In general, when the partial and/or complete substitution of NV by agricultural and pasture cultivation has a reduction in soil OC and TN; however, the establishment of these cropping systems with high biomass production species that are adapted to the Paraiba Sertão region, can generate an additional benefit in increasing soil organic carbon and total nitrogen, as can be seen in the values found in Tables 3 and 4.

Similar to the results for C, the highest values of N found in the soil of native vegetation system followed by sparse vegetation, pasture, annual crops and permanent agriculture systems (Table 4); in the environments analyzed, with the exception of permanent agriculture system, the average nitrogen values decreased with a significant difference with increasing depth, corroborating Lima et al. (2011) that found soils of semi-arid Piauí, in the layer 0-10cm, amounts of nitrogen of 0.22 g kg^{-1} for native vegetation and 0.20 g kg^{-1} for traditional soil management system. Similar result was found by Costa (2011) evaluating soil nitrogen levels in semi-arid regoins; this author found that the nitrogen content was 0.52 g kg^{-1} for pastures that is similar to the result of this research.

Mean values of N decreased with increasing depth; similar results were found by Bernardi et al. (2007) in Piraipaba, CE, which found nitrogen values 0.77, 0.33 and 0.30 g kg^{-1} in Caatinga environment in the depths 0 to 10, 10 to 20 and 20 to 40 cm, respectively.

The organic carbon (CStock) and nitrogen (NStock) stocks were also significantly altered by management systems and depth (Tables 5 and 6) where the depth of 0-10 cm, the lowest values of C and N stocks were observed in PA system, probably due to the lower input of organic material deposited on the soil. Even in this management system there was no significant difference in values of C and N stocks in relation to the depths of

Table 4. Total nitrogen (g kg^{-1}) of the management systems as a function of depth.

Depth (cm)	Management systems				
	Native vegetation	Sparse vegetation	Pasture	Annual crops	Permanent agriculture
0-10	1.1^{aA}	0.8^{aB}	0.7^{aBC}	0.7^{aBC}	0.6^{aC}
10-20	0.9^{aA}	0.6^{bB}	0.5^{abB}	0.5^{bB}	0.5^{aB}
20-30	0.6^{bA}	0.5^{bA}	0.5^{bA}	0.6^{abA}	0.5^{aA}
30-40	0.6^{bAB}	0.4^{bAB}	0.4^{bAB}	0.4^{bB}	0.6^{aA}

Means followed by the same lowercase letters in columns and uppercase letters in the lines do not differ by Tukey test up to 5% probability.

Table 5. Carbon stocks (Mg ha^{-1}) of the management systems as a function of depth

Depth (cm)	Management systems				
	Native vegetation	Sparse vegetation	Pasture	Annual crops	Permanent agriculture
0-10	14.93^{aA}	13.49^{aA}	11.37^{aAB}	11.98^{aAB}	9.04^{aB}
10-20	12.04^{abA}	9.52^{bA}	8.59^{abA}	8.49^{abA}	8.36^{aA}
20-30	9.32^{bAB}	8.07^{bAB}	6.79^{bB}	11.06^{abA}	8.81^{aAB}
30-40	10.17^{bA}	7.27^{bA}	8.38^{abA}	7.53^{bA}	10.49^{aA}

Means followed by the same lowercase letters in columns and capital letter in the lines do not differ by Tukey test up to 5% probability.

the soil layers corroborating Maia et al. (2007) that evaluated management systems in Sobral, CE, found that the values of C stock did not decrease with increasing depth.

In all other management systems analyzed in this study, at a depth of 0-10 cm, the values of C and N stocks were higher, especially in NV and SV systems, corroborating Campanha et al. (2009) and Pinheiro et al. (2007). However, in general, the total of the values of C stocks corresponding to the depth of 0-40 cm, was observed in descending sequence NV (46.46 Mg ha^{-1}) > AC (39.06 Mg ha^{-1}) > SV (38.35 Mg ha^{-1}) > PA (36.70 Mg ha^{-1}) > P (35.13 Mg ha^{-1}). Smaller soil carbon stocks in the areas of permanent agriculture and pasture may be related to their low productivity and intensive grazing, which in course of time, contribute to a lower contribution of vegetable residue.

According to Canellas et al. (2007), the maintenance of the native vegetation is important because it is able to promote and maintain minimal soil fertilization. Pulrolnik et al. (2009) studying the soil C and N stocks under different management systems, observed the CStocks of 2.95; 2.78 and 6.96 Mg ha^{-1}; and NStocks 0.071; 0.071 and 0.180 Mg ha^{-1} in soils under Cerrado, pasture and cultivated with eucalyptus, respectively. Giongo et al. (2011) evaluating the carbon stocks in semi-arid Pernambuco, found that carbon stocks in preserved Caatinga, altered Caatinga and Buffel grass pasture area and irrigated mango systems at a depth of 0-20 cm were 15.48; 12.26, 9.60 and 6.92 Mg ha^{-1}, respectively. These last three results are similar to those observed in the present study related to natural vegetation, sparse vegetation and pasture (Table 5).

Variations of average values of NStocks as a function of management systems and the depths of the soil layers followed the same pattern of changes in the values of CStocks, as can be seen in Table 7. Similar results were found by Barros et al. (2013). In other depths, soil carbon and nitrogen stocks, suffered the effect of soil density in view of their significant difference between the environments studied, corroborating Pedra et al. (2012).

The removal of native vegetation to the introduction of agriculture leads to important changes in the dynamics of organic substances. In this study, it was observed that the values of the carbon stocks in the management systems under the SV, P, AC and PA were lower around 22.57, 28.82, 28.05 and 30.96%, respectively, in relation to the corrected C stocks in the soil of NV (Figure 1). Thus, during the period of this research, probably the NV is performing the role of sequestering (Storer) carbon, as presented Cstocks values superior to other management systems (SV, P, AC and PA) which are playing a role of emitting CO_2-C. So it is important to maintain the areas of NV to offset emissions arising from crop and livestocks production systems in Paraiba Sertão.

Conclusions

The lower values of bulk density were presented in the

Table 6. Nitrogen stocks (Mg ha^{-1}) of the management systems as a function of depth.

Depth (cm)	Management systems				
	Native vegetation	Sparse vegetation	Pasture	Annual crops	Permanent agriculture
0-10	1.45^{aA}	1.26^{aA}	1.03^{aAB}	1.16^{aAB}	0.82^{aB}
10-20	1.16^{abA}	0.89^{bA}	0.81^{abA}	0.80^{bA}	0.77^{aA}
20-30	0.86^{bAB}	0.73^{bAB}	0.58^{bB}	1.01^{abA}	0.81^{aAB}
30-40	0.91^{bA}	0.65^{bA}	0.77^{abA}	0.67^{bA}	1.00^{aA}

Means followed by the same lowercase letters in columns and capital letter in the lines do not differ by Tukey test up to 5% probability.

Table 7. Mean values of nitrogen stock (Mg ha^{-1}) of the management systems as a function of depth.

Depth (cm)	Management systems				
	Native vegetation	Sparse vegetation	Pasture	Annual crops	Permanent agriculture
0-10	1.45^{aA}	1.26^{aA}	1.03^{aAB}	1.16^{aAB}	0.82^{aB}
10-20	1.16^{abA}	0.89^{bA}	0.81^{abA}	0.80^{bA}	0.77^{aA}
20-30	0.86^{bAB}	0.73^{bAB}	0.58^{bB}	1.01^{abA}	0.81^{aAB}
30-40	0.91^{bA}	0.65^{bA}	0.77^{abA}	0.67^{bA}	1.00^{aA}

Means followed by the same lowercase letters in columns and capital letter in the lines do not differ by Tukey test up to 5% probability.

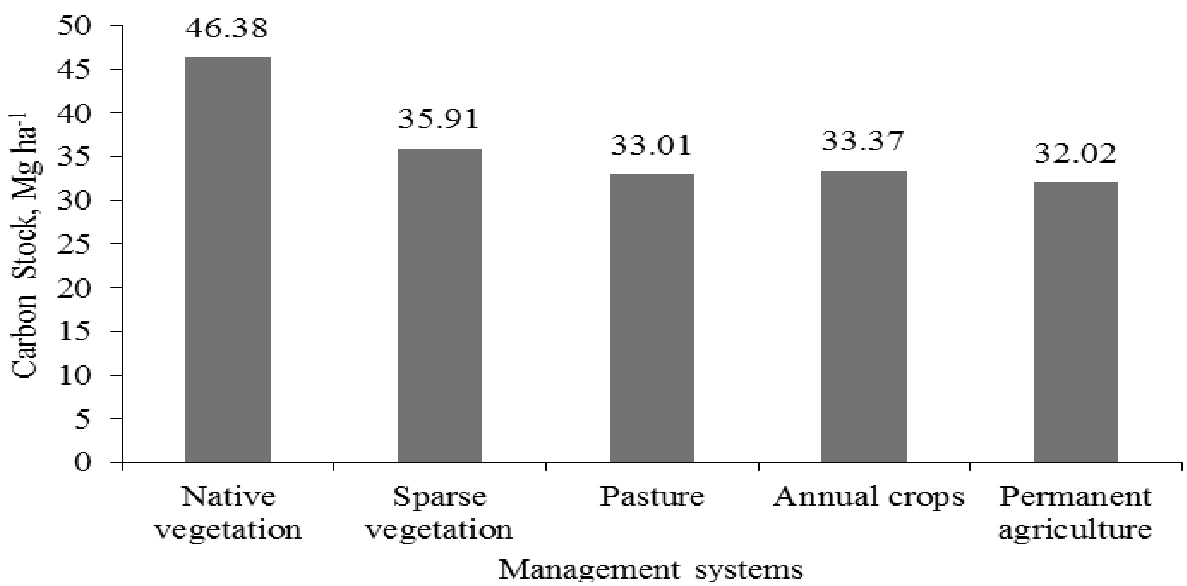

Figure 1. Soil carbon stocks corrected for each area (native vegetation (NV), sparse vegetation (SV), pasture (P), annual crops (AC); permanent agriculture (PA)) in four depths (0-40 cm).

area of native vegetation in relation to the management systems as well as in depth 0-10 cm in relation to depths of all management systems. The implementation of agricultural systems in areas that had native vegetation decreased the C and N contents and stocks, in the same way, these values decreased relative soil layers analyzed. The various systems of agricultural and livestock production performed the role of C- CO_2 emitter when compared with the native vegetation.

Conflict of Interest

The authors have not declared any conflict of interest.

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REFERENCES

Barros JDS, Chaves LHG, Chaves IB, Farias CHA, Pereira WE (2013). Carbon and nitrogen stocks in soil management systems, trays Coastal Paraibanos . Rev. Caatinga. 26(1):35-42.

Bernardi ACC, Machado PLOA, Madari BEM, Tavares SRL, Campos DVB, Crissóstomo LA (2007). Carbon and nitrogen stockss of an Arenosol Under irrigated ftruit orchards in Semiarid Brazil. Sci. Agricola. 64(1):169-175.

Black CA, Evans DD, White JL, Ensminger LE, Clark FE (1965). Methods of Soil Analysis, Part II. American Society of Agronomy, Madison, Wisconsin, USA. pp. 1367-1378.

Boddey RM, Alves BJR, Urquiaga S, Jantalia LMN, Madari BE, Milori DMBP, Machado PLOA (2012). Carbon stocks in Brazil amount of soil and accumulation and preservation mechanism. In: Lima MA, Boddey RM, Alves BJR, Machado PLOA, Urquiaga S (2012). Carbon stocks and emissions of greenhouse gases in the Brazilian agriculture . Brasília, DF: EMBRAPA, pp. 33-82.

Campanha MM, Nogueira RS, Oliveira TS, Teixeira AS, Romero RE (2009). Levels and carbon stocks in the soil of agroforestry and conventional systems in the Brazilian semiarid. Sobral, CE: Embrapa, Technical Circular, n P. 42.

Canellas LP, Baldotto MA, Busato IG, Marciano CR, Menezes SC, Silva NM, Rumjanek VM, Velloso ACX, Simões ML, Martin-Neto L (2007). Stock and quality of organic matter of a soil cultivated with cane sugar for a long time. Rev. Bras. Ci. Solo. 31:331-340. http://dx.doi.org/10.1590/S0100-06832007000200015

Colonego JC, Santos CH, Tiritan CS, Cunha Jr B (2012). Carbon stocks and physical properties of soils under different management systems. Rev. Caatinga 25(2):128-135.

Corsini PC, Ferraudo AS (1999). Cropping systems effects on soil bulk density and macroporosity and root development of maize in Latosolic . Pesq. Agric. Bras. 34:289-298.

Costa AA (2011). Content and carbon storage, Nt, Ca and Mg in soils of different agricultural systems : Biome and semi-arid savannah biome. Encicl. Biosf. 7(12):1-6.

Coutinho RP, Irquiaga S, Boddey RM, Alves BJR, Torres AQA, Jantalia CP (2010). Carbon and nitrogen stock and N2O emissions in different land uses in the Atlantic Forest. Pesq. Agrop. Bras. 45(2):195-203. http://dx.doi.org/10.1590/S0100-204X2010000200011

EMBRAPA (1997). EMBRAPA–Brazilian Agricultural Research Corporation. National Center for Soil Survey. Manual of soil analysis methods. 2 ed, Rio de Janeiro. EMBRAPA.

FAO (1990). FAO (Roma, Italia). Global Soil Map: Revised legend. Rome (Reports on World Soil Resources, 60), 142 pp.

Ferreira DF (2000). Statistical analysis through SISVAR (System for Analysis of Variance) for Windows version 4.0. In: Annual Meeting of the Brazilian Region of the International Society of Biometrics, 45, São Carlos. Proceedings San Carlos: UFSCar.

Fracetto FJC, Fracetto GGM, Cerri CC, Feigl BJ, Siqueira NM (2012). Carbon and nitrogen stocks in the soil cultivated with castor Caatinga. Rev. Bras. Ci. Solo. 36(5):1545-1552. http://dx.doi.org/10.1590/S0100-06832012000500019

Giongo V, Galvão SR, Mendes MAS, Gava CAT, Cunha TJF (2011). Carbon Balance in Brazilian Tropical Semiarid. Dynamic Soil Dynamic Plant 5(1):12-20.

Guareschi RF, Pereira MG, Perin A (2012). Carbon stock in Hapludox under different management systems. Rev. Bras. Ci. Agrárias. 7(4):597-602.

Lima SS, Leite LFC, Oliveira FC, Costa EB (2011). Chemical attributes and carbon stocks and nitrogen in red-yellow Argisols under agroforestry systems and cut and burn agriculture in northern Piauí. Rev. Árvore. 35(1):51-60. http://dx.doi.org/10.1590/S0100-67622011000100006

Maia SMF, Xavier FAZ, Oliveira TS, Mendonça ES, Araújo Filho JA (2006). Impact of agroforestry and conventional systems on soil quality in Ceará semiarid. Rev. Árvore 30(5):837-848. http://dx.doi.org/10.1590/S0100-67622006000500018

Maia SMF, Xavier FAS, Oliveira TS, Mendonça ES, Araújo Filho JA (2007). Organic carbon pools in a Luvisol under agroforestry and conventional farming systems in the semi-arid region of Ceará, Brazil. Agroforest. Syst. 71(2):127-138. http://dx.doi.org/10.1007/s10457-007-9063-8

Nogueira RS, Oliveira TS, Teixeira AS, Araújo Filho JAA (2008). Organic carbon and phosphorus redistribution through runoff in conventional and agroforestry farming systems in semi- arid Ceará. Ceres 55(4):327-337.

Nunes LAPL, Araújo Filho JA, Holanda Jr. EV, Menezes RIQ (2009). Impact of burned and windrowing of organic waste in biological soil under Caatinga in northeastern semiarid. Rev. Caatinga 22(1):131-140.

Oliveira JT, Moreau AMSS, Paiva AQ, Menezes AA, Costa OV (2008). Physical and organic carbon from soils under different types of land use. Rev. Bras. Ci. Solo. 32(1):2821-2829. http://dx.doi.org/10.1590/S0100-06832008000700028

Pedra WN, Pedrotti A, Silva TO, Macedo FL, Gonzaga MIS (2012) Carbon stocks and nitrogen under different management conditions of a Red Ultisol cultivated with sweet corn in the coastal tableland of Sergipe . Semina: Ciências Agrárias 33(6):2075-2090.

Pinheiro EFM, Lima E, Ceddia MB, Urquiga S, Alves BJR, Boddey RM (2007). Carbon and nitrogen stocks in an Ultisol cultivated with sugar -cane : influence of burning or permanence of the straw. Bulletin of Research and Development 17. Serpédica: Embrapa Agrobiology.

Portugal AF, Jucksch I, Schaefer CEGR, Wendlin B (2008). Determination of total stocks of carbon and nitrogen and its fractions in agricultural systems deployed in Red-Yellow Ultisol. Rev. Bras. Ci. Solo. 32(5):2091-2100. http://dx.doi.org/10.1590/S0100-06832008000500030

Pulrolnik K, Barros NF, Silva IR, Novais RF, Brandani CB (2009). Carbon and nitrogen stocks in fractions labile and Stable Organic Matter Soil Under Eucalyptus, Pasture and Cerrado in Jequitinhonha Valley - MG. Rev. Bras. Ci. Solo 33(5):1125-1136. http://dx.doi.org/10.1590/S0100-06832009000500006

Silva JRC (2000). Erosion and productivity in semi -arid soils. In: Oliveira TS, Assisi Jr. RN, Romero RE (2000). Agriculture, sustainability and the semi -arid. Fortaleza: UFC / SBCS, cap.10:169-213.

Sisti CPJ, Santos HP, Kohhann R, Alves BJR, Urquiaga S, Boddey RM (2004). Change in carbon and nitrogen stockss in soil under 13 years of conventional or zero tillage in Southern Brazil. Soil Till. Res. 76(1):39-58. http://dx.doi.org/10.1016/j.still.2003.08.007

Stevenson FJ (1982). Humus chemistry, genesis, composition, reaction. New York: John Wiley.

Vasconcelos RFB, Cantalice JRB, VS Oliveira, Costa, YDJ, Cavalcante DM (2010). Aggregate stability of a Typic distrocoeso a Coastal Plain under different inputs of organic waste from cane sugar. Rev. Bras. Ci. Solo 34(2):309-316.

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Full Length Research Paper

Effect of nitrogen fertilization associated with inoculation of *Azospirillum brasilense* and *Herbaspirillum seropedicae* on corn

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The growing interest in the use of inoculants with diazotrophic bacteria that promote plant growth, providing increase in crop productivity, occurs because of the high costs of chemical fertilizers and the concern about environmental quality. Given the above, this study aimed to evaluate, in field conditions, the effect of nitrogen fertilization and inoculation with *Azospirillum brasilense* and *Herbaspirillum seropedicae* on the productivity, phytotechnical parameters and nutritional state of corn. The experiment was set in a randomized block design, with nine treatments and six replicates: Control without N and without inoculation; *A. brasilense* inoculation without N; *H. seropedicae* inoculation without N; 30 kg ha^{-1} of N at the sowing; *A. brasilense* + 30 kg ha^{-1} of N at the sowing; *H. seropedicae* + 30 kg ha^{-1} of N at the sowing; 30 kg ha^{-1} of N at the sowing + 90 kg ha^{-1} of N in covering; *A. brasilense* + 30 kg ha^{-1} of N at the sowing + 90 kg ha^{-1} of N in covering; and *H. seropedicae* + 30 kg ha^{-1} of N at the sowing + 90 kg ha^{-1} of N in covering. The evaluated parameters were: plant height, stem diameter, ear insertion height, ear weight, ear length, number of grain rows per ear, number of grains per ear, ear base diameter, weight of 1,000 grains, shoot dry weight, yield, chlorophyll content, leaf nutrient content and grain nutrient content. The nitrogen fertilization associated with inoculation of *A. brasilense* and *H. seropedicae* positively influenced ear weight, ear diameter, number of grains per ear, shoot dry weight, yield and chlorophyll content of corn plants. The contents of N, P, K and Zn in corn leaves increased with nitrogen fertilization and inoculation with *A. brasilense* and *H. seropedicae*. The inoculation with *A. brasilense* without nitrogen fertilization promoted higher accumulations of N, K, Ca and Mg in grains compared with the treatments inoculated with *A. brasilense* and *H. seropedicae* and fertilized with 30 and 120 kg ha^{-1} of N. The inoculation with *A. brasilense* or *H. seropedicae* associated with nitrogen fertilization may lead to a reduction in the use of synthetic nitrogen fertilizers in corn cultivation.

Key words: *Zea mays* L., nitrogen, diazotrophic bacteria.

INTRODUCTION

Among mineral nutrients, nitrogen (N) is one of the most important and limiting for corn productivity, and its application is required in large amounts in order to meet crop demand (Dotto et al., 2010). The economic and

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environmental costs related to N fertilization have stimulated the search for alternatives that might reduce the use of these fertilizers, without any decrease in production. One way to make it a possible low-cost production without harming the environment is the use of soil biological resources, like diazotrophic bacteria, which are also considered as growth-promoting bacteria, for their capacity to fix nitrogen (N_2) for the plant and produce growth hormones, such as auxins and gibberellins (Dobbelaere et al., 2002; Radvan et al., 2002).

The Biological Nitrogen Fixation (BNF) process in grass crops is not as efficient as it is in soybean, to which even 94% of the N required by plant can be supplied by BNF (Hungria et al., 2006). In grass crops, the transfer of the fixed N to the plant occurs slowly and only a small amount becomes available to plant; therefore, BNF by these bacteria in association with grass crops is only able to meet plant nitrogen demand partially (Hungria et al., 2011).

Among the diazotrophic microorganisms found in association with grass crops, the species *Azospirillum, Herbaspirillum* and *Burkholderia* are currently the most studied groups. Bacteria capable of fixing atmospheric nitrogen, such as the genera *Azospirillum* and *Herbaspirillum*, have been isolated in rice, wheat, corn and sugarcane plants (Reis Júnior et al., 2004; 2008; Perin et al., 2006; Rodrigues et al., 2006). The results of inoculations with these genera are variable and significant effects on grain production and nutrient absorption have already been reported (Kennedy et al., 2004; Guimarães et al., 2007; Ferreira et al., 2010; Hungria et al., 2010; Braccini et al., 2012). In this context, Alves (2007) verified that inoculation with strains of the genus *Herbaspirillum* contributed with up to 34% of the absorbed N in corn plants. Alves et al. (2011), found that inoculation with the strain BR11417 of *Herbaspirillum seropedicae* contributed in average with 26% of the N necessary for the development of corn. García de Salomone et al. (1996) verified that some corn varieties cultivated in pots fixed around 58% of their N requirement when inoculated with *Azospirillum* sp.

Most studies related to this topic address only the isolation of these bacteria in corn plants and their biochemical studies in laboratory; while studies that are more comprehensive, in field conditions, showing the plant-microorganism-environment interaction related to crop development, are scarce (Dotto et al., 2010). Therefore, the knowledge about the potentialities and the use of these bacteria as an alternative for nitrogen nutrition for many economically important Poaceae crops, such as corn, may result in great impact, not only on production volume and size of planted area, but also on their socioeconomic and environmental importance, which makes the study on the agronomic efficiency of these bacteria an essential and economically viable strategy. Given the above, this study aimed to evaluate, in field conditions, the effect of nitrogen fertilization and inoculation with *Azospirillum brasilense* and *H. seropedicae* on the productivity, phytotechnical parameters and nutritional state of corn.

MATERIALS AND METHODS

The experiment was carried out in the experimental field of Embrapa Western Region Agriculture, in Dourados-MS, Brazil, from March to July of 2012. The geographical coordinates are 22° 14' S and 54° 9' W, with average altitude of 450 m. The climate of the region is Cwa, according to Köppen’s classification. The soil was classified as distroferric Red Latosol, with very clayey texture (Embrapa, 2013). Average data of temperature and rainfall during the experiment were obtained from the Weather Station of Embrapa Western Region Agriculture, in Dourados-MS, and are shown in Figure 1.

The results of soil chemical analysis, in the layer of 0-20 cm, before the experiment was installed, are as follows: pH ($CaCl_2$): 4.5; O.M.: 31.18 g dm^{-3}; C: 18.13 g dm^{-3}; P (mehlich): 22.07 mg dm^{-3}; K: 6.0 $mmol_c$ dm^{-3}; Ca: 35.4 $mmol_c$ dm^{-3}; Mg: 8.7 $mmol_c$ dm^{-3}; Al: 4.8 $mmol_c$ dm^{-3}; H+Al: 62.1 $mmol_c$ dm^{-3}; SB: 50.1 $mmol_c$ dm^{-3}; CEC: 112.2 $mmol_c$ dm^{-3}; Base saturation: 44.65%; Zn: 1.65 mg dm^{-3}; Cu: 9.27 mg dm^{-3}; Fe: 29.14 mg dm^{-3}; and Mn: 24.06 mg dm^{-3}. Granulometric analysis showed the following values: 215 g kg^{-1} of sand, 115 g kg^{-1} of silt and 670 g $kg^{-1}$of clay. Soil correction was performed one month before sowing, with 1720 kg ha^{-1} of dolomitic limestone (RNV 100%), considering the results of soil chemical analysis, aiming to increase base saturation to 60%. The area was irrigated after crop installation and in periods with high water deficit. The adopted experimental design was randomized blocks, with nine treatments and six replicates: 1) Control without N and without inoculation; 2) *A. brasilense* inoculation without N; 3) *H. seropedicae* inoculation without N; 4) 30 kg ha^{-1} of N at the sowing; 5) *A. brasilense* + 30 kg ha^{-1} of N at the sowing; 6) *H. seropedicae* + 30 kg ha^{-1} of N at the sowing; 7) 30 kg ha^{-1} of N at the sowing + 90 kg ha^{-1} of N in covering; 8) *A. brasilense* + 30 kg ha^{-1} of N at the sowing + 90 kg ha^{-1} of N in covering; 9) and *H. seropedicae* + 30 kg ha^{-1} of N at the sowing + 90 kg ha^{-1} of N in covering.

The used seeds of the simple hybrid P3646H were previously inoculated with a liquid inoculant containing a combination of two strains of *A. brasilense* (Ab-V5 and Ab-V6) and a peat-based inoculant containing the Z-94 strain of *H. seropedicae*, produced by Embrapa Agrobiology, Seropédica-RJ. The applied dose was 150 ml of peat-based inoculant for each 50 kg of corn seeds. For the inoculation with the Z-94 strain of *H. seropedicae*, 60 ml of a sugary solution at 10% (m/v) were added to each 10 kg of seeds, aiming to increase the adhesion of the inoculant to the seeds. Broadcast fertilization was performed at sowing, with later incorporation, by applying 300 kg ha^{-1} of a 0-20-20 formulation in order to supply 60 kg ha^{-1} of P_2O_5 and K_2O, respectively. Sowing was performed manually, with the aid of a hand-held corn planter (known as “matraca”), planting two seeds per hole and six plants per meter were left after thinning. Each experimental unit was composed of five 5-m long rows, spaced 0.90 m apart, with a population of 6000 plants/hectare. The three central rows were considered as the useful plot area, excluding 0.5 m of each side. Nitrogen fertilization was applied using 30 kg ha^{-1} of N in the furrow and 90 kg ha^{-1} of N divided into two applications of 45 kg ha^{-1}, in covering, as urea (45%), in all the plot area, at the development stages of V4 and V7, respectively.

At the flowering stage (emergence of feminine inflorescence) of the crop, to 60 days after the emergency of plants, leaf samplings were performed, according to the methodology proposed by Malavolta et al. (1997), in order to determine nutrient content in the

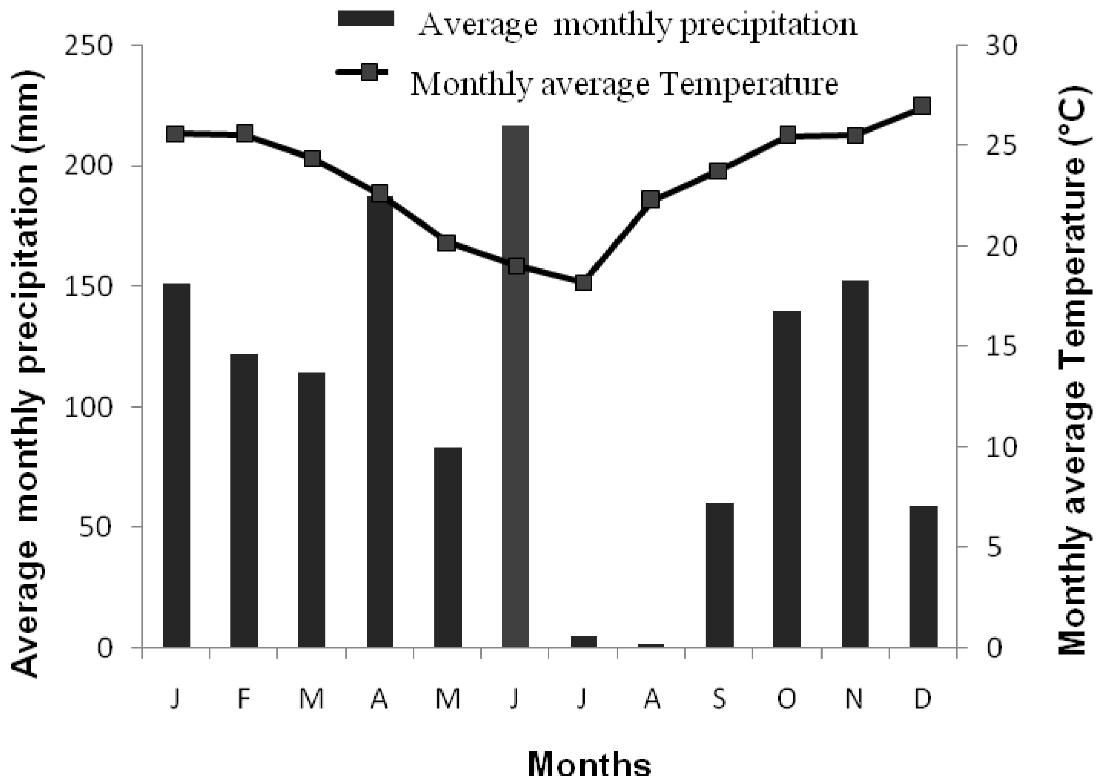

Figure 1. Monthly average rainfall (mm) and temperature (°C), recorded at the Weather Station of Embrapa Western Region Agriculture, in Dourados-MS, Brazil, in 2012.

plant leaf tissue. For this, the middle third, with leaf veins, of the leaf opposite and below the primary ear was collected, totaling 10 leaves per experimental unit and, in the same phenological stage, leaf chlorophyll content was determined with the aid of a chlorophyll meter (model SPAD-502).

All the collected plant material was washed in running water, 0.1 mol L^{-1} HCl solution and deionized water. Samples were accommodated in paper bags, dried in a forced-air oven at 65°C for 72 h and then ground. Ground samples were subjected to sulfuric digestion and nitric-perchloric digestion, followed by the determinations of N, P, K, Ca, Mg, S, Zn, Cu, Fe and Mn leaf contents, using the methodology described by Embrapa (2009). At the harvest, nutrient contents were also determined in corn grains.

The corn harvest was performed manually, to 150 days after the emergency, collecting all ears of a useful plot area of 9.0 m^2. In order to determine production components, 10 representative ears were sampled per plot, outside the area of grain production. The following parameters were evaluated: ear weight, ear length, number of grain rows per ear, number of grains per ear, ear base diameter and weight of 1,000 grains. For the plant, the following parameters were evaluated: plant height, stem diameter and ear insertion height. In order to determine grain productivity, ears were threshed with the aid of a manual machine and then weighed. The obtained results were converted to kg ha^{-1}, correcting moisture to 13% on a wet basis. Shoot dry weight of plants was estimated by the sampling of three plants in each plot. The determination of shoot dry weight was performed through the drying of plant samples in a forced-air oven at 65°C for 72 h. Shoot dry weight data were expressed in g/plant. The obtained results were subjected to analysis of variance and means were compared by Tukey test at 5% of probability, using the statistical analysis software SISVAR (Ferreira, 2000).

RESULTS AND DISCUSSION

There was significant difference ($p \leq 0.05$) for ear weight, ear diameter, number of grains per ear, shoot dry weight, productivity and chlorophyll content in response to nitrogen fertilization and inoculation with *A. brasilense* and *H. seropedicae* (Tables 1 and 2). Ear weight showed higher values in the treatment corresponding to inoculation with *H. seropedicae* + 120 kg ha^{-1} of N, being higher than the control (without either inoculation or N) and the treatment only inoculated with *H. seropedicae*, and similar to the other evaluated treatments (Table 1). The values ranged from 217.42 g/plant (control) to 249.42 g/plant (*H. seropedicae* + 120 kg ha^{-1} of N), with increases of 14.71% compared with the control (Table 1). The ear diameter and the number of grains per ear were higher in the treatment fertilized with 120 kg ha^{-1} of N, statistically differing ($p \leq 0.05$) from the control, the treatment inoculated with *H. seropedicae* and that inoculated with *A. brasilense* + 30 kg ha^{-1} of N (Table 1). Guimarães et al. (2012) verified that the inoculation of corn seeds with *Azospirillum* spp., in combination with nitrogen fertilization (60 kg ha^{-1} of N), resulted in ears with higher diameter and higher number of grain rows.

It was not found significant effect of nitrogen fertilization associated with inoculation of *A. brasilense* and *H. seropedicae* for plant height, ear insertion height, stem

Table 1. Plant height (PH), ear insertion height (EIH), stem diameter (SD), ear weight (EW), ear length (EL), ear diameter (ED), number of grain rows per ear (NGRE) and number of grains per ear (NGE) of corn plants in response to nitrogen fertilization and inoculation with *Azospirillum brasilense* and *Herbaspirillum seropedicae*. Dourados-MS, Brazil (2012).

Treatments	PH	EIH	SD	EW	EL	ED	NGRE	NGE
	(cm)		(mm)	(g)	(cm)	(mm)		
1. Control	216.30	122.63	21,32	217.42 b	17.04	51.45 b	15.44	493.16 b
2. *A.brasilense*	218.40	124.00	20.20	220.52 ab	17.03	52.72 ab	15.52	517.16 ab
3. *H. seropedicae*	219.30	122.63	20.31	216.23 b	17.13	51.53 b	15.66	501.00 b
4. 30 kg ha^{-1} N	222.20	126.20	20.51	242.19 ab	18.12	53.12 ab	15.47	543.38 ab
5. *A.brasilense* + 30 kg ha^{-1} N	216.80	122.93	20.30	224.08 ab	17.57	51.43 b	15.66	510.33 ab
6. *H. seropedicae* + 30 kg ha^{-1} N	218.83	124.20	21.48	220.63 ab	17.82	52.59 ab	15.61	544.30 ab
7. 30 kg ha^{-1} N + 90 kg ha^{-1} N	223.36	125.06	21.62	245.97 ab	17.89	53.83 a	16.55	576.66 a
8. *A. brasilense* + 120 kg ha^{-1} N (30+90)	223.66	123.60	21.18	238.82 ab	17.82	53.08 ab	16.00	530.64 ab
9. *H. seropedicae* + 120 kg ha^{-1} N (30+90)	228.86	127.46	22.09	249.42 a	17.82	53.34 ab	16.00	554.94 ab
Average	220.85	124.30	21.00	230.59	17.64	52.57	15.73	530.17
Teste F	1.40 ns	0.51 ns	1.00 ns	3.91*	1.63 ns	3.41*	0.93 ns	2.95*
CV (%)	3.78	4.59	7,98	7.14	5.15	2.26	5.60	7.32

* e ns– significant 5% probability and non-significant, respectively. Medium followed by the same letter in the columns, do not differ statistically between them by Tukey test, the 5% probability. CV: coefficient of variation.

Table 2. Shoot dry weight (SDW), productivity (PRO), weight of 1,000 grains (W1000) and chlorophyll content (CLO) of corn plants in response to nitrogen fertilization and inoculation with *Azospirillum brasilense* and *Herbaspirillum seropedicae*. Dourados-MS, Brazil (2012).

Treatments	SDW	PRO	W1000	CLO
	(g)	(kg ha^{-1})	(g)	(SPAD)
1. Control	246.63 b	9231.71 b	358.67	61.58 b
2. *A.brasilense*	257.26 ab	9078.41 b	352.04	65.18 abc
3. *H. seropedicae*	258.50 ab	9023.88 b	351.03	61.85 c
4. 30 kg ha^{-1} N	271.03 ab	9302.05 b	350.76	61.60 c
5. *A.brasilense* + 30 kg ha^{-1} N	274.40 ab	9531.75 ab	351.55	63.45 abc
6. *H. seropedicae* + 30 kg ha^{-1} N	293.96 ab	9133.32 b	357.62	62.51 bc
7. 30 kg ha^{-1} N + 90 kg ha^{-1} N	276.68 ab	10146.52 a	356.35	69.06 a
8. *A. brasilense* + 120 kg ha^{-1} N (30+90)	283.83 ab	9861.37 ab	362,27	69.06 a
9. *H. seropedicae* + 120 kg ha^{-1} N (30+90)	314.80 a	9858.23 ab	359.43	68.18 ab
Average	275.23	9463.00	355.52	64.72
Teste F	2.27*	4.76*	0.57 ns	5.92*
CV (%)	12.21	4.81	3.90	5.04

* e ns– significant 5% probability and non-significant, respectively. Medium followed by the same letter in the columns, do not differ statistically between them by Tukey test, the 5% probability. CV: coefficient of variation.

diameter, ear length, number of grain rows per ear and weight of 1,000 grains (Tables 1 and 2). Similar results were obtained, also in field conditions, by Lana et al. (2012), who did not observe positive response of the nitrogen fertilization and inoculation with *Azospirillum* sp. for plant height and ear insertion height in corn plants; by Braccini et al. (2012), who did not verify effect of inoculation with *A. brasilense* on the weight of 1,000 grains of corn; and by Dotto et al. (2010), who did not find significant effect of inoculation with *H. seropedicae* on stem diameter, ear insertion height, ear weight, cob weight, ear length and weight of 1.000 grains of corn.

The shoot dry weight yield ranged from 246.63 g/plant in the control treatment to 314.80 g/plant in the treatment inoculated with *H. seropedicae* + 120 kg ha^{-1} of N. It should be pointed out that this last treatment proved to be superior ($p \leq 0.05$) to the control and similar to the other ones (Table 2). The increase in shoot dry weight was of 27.64% in relation to the control (without either fertilization or inoculation). It is worth noticing that this higher shoot dry weight production of plants inoculated with *H. seropedicae* and supplied with 120 kg ha^{-1} of N may have been favored by the production of growth-promoting substances by bacteria. Reis Junior et al. (2008) observed increase in dry weight of corn plants inoculated with *Azospirillum* spp. Lana et al. (2012) verified that inoculation with *Azospirillum* spp. without nitrogen fertilization increased dry weight of corn plants in 7.2%. Braccini et al. (2012) found relative increase in dry weight production with the inoculation of corn seeds with *A.brasilense*. Similar results were also found by Quadros (2009), with inoculation of *Azospirillum* spp. in corn and by Ferreira et al. (2010) and Guimarães et al. (2010) in rice plants inoculated with *H. seropedicae.*

The highest corn grain yields were obtained in the treatment corresponding to fertilization with 120 kg ha^{-1} of N, which was not statistically different from the treatment inoculated with *H. seropedicae* + 120 kg ha^{-1} of N and from that inoculated with *A. brasilense* + 30 and 120 kg ha^{-1} of N (Chart 2). It is noteworthy that the treatment corresponding to the fertilization with 120 kg ha^{-1} of N promoted an increase in grain yield of about 10%, compared with the control, which did not have either inoculation or nitrogen fertilization. As for the treatments with inoculation of *H. seropedicae* + 120 kg ha^{-1} of N and those inoculated with *A. brasilense* + 30 and 120 kg ha^{-1} of N promoted increases in grain yield of about 6.78, 6.82 and 3.25%, respectively, compared with the control. In average, these treatments promoted an increase of 518.74 kg ha^{-1} of corn grains compared with the control, which represents a gain of 8.64 sacks per hectare, suggesting the applicability of inoculation associated with nitrogen fertilization in corn cultivation.

Various studies have so far reported beneficial effect of inoculation with *Azospirillum* or *Herbaspirillum* on corn. Kappes et al. (2013) found increases of 9.4% in corn grain yield when seeds were inoculated with *A. brasilense*.

Alves (2007) observed percent increases of 24 and 34% in corn yield with the use of *H. seropedicae* in second and first corn cropping seasons, respectively, and that inoculation can supply up to 40 kg ha^{-1} of N. Hungria et al. (2011) and Lana et al. (2012) verified that inoculation with *A. brasilense* in corn promoted increase in grain yield of 26 and 15.4%, respectively. In studies with wheat and rice, Dalla Santa et al. (2008) and Pedraza et al. (2009) also reported that inoculation with *Azospirillum* spp. increased grain yield compared with the control (without either N or inoculant).

Increases in shoot dry weight and grain yield of corn in response to inoculation can be attributed to the stimulus that diazotrophic bacteria provide to the development of the root system, with increase in root hair density, length, volume and number of lateral roots, resulting in higher capacity to absorb and use water and nutrients, as reported by Hungria et al. (2011) and Huergo et al. (2008). Based on the results already shown, it is important to point out that most treatments with diazotrophic bacteria inoculation combined with 30 kg ha^{-1} of N showed results similar to those from the treatment with the highest N dose (120 kg ha^{-1} of N) regarding ear weight, ear diameter, number of grains per ear, shoot dry weight production and grain yield (Tables 1 and 2). It allows one to suggest that the application of 30 kg ha^{-1} of N is less costly than the application of 120 kg ha^{-1} of N, which in turn can lead to a reduction in the use of synthetic nitrogen fertilizers and, consequently, reduction in production costs.

The highest chlorophyll contents were verified in the treatments with inoculation of *A. brasilense* combined with 120 kg ha^{-1} of N or only fertilized with 120 kg ha^{-1} of N, which did not differ statistically ($p \geq 0.05$) from the treatments with only the inoculation of *A. brasilense* or also supplied with 30 kg ha^{-1} of N, and from the treatment with inoculation of *H. seropedicae* + 120 kg ha^{-1} of N (Table 2). It is observed that leaf chlorophyll content is positively correlated with N content in the plant (BOOIJ et al., 2000). Many studies have demonstrated that the addition of N in corn has a direct effect on root exudation, increasing the supply of carbon sources to bacteria, stimulating their colonization and the effectuation of the inoculation (Kolb and Martin, 1987), as well as it can benefit biological nitrogen fixation (Dalla Santa et al., 2004; Alves, 2007; Ferreira et al., 2011). It occurs because, under N deficiency conditions, the plant cannot either excrete, deposit or exudate sufficient organic compounds and/or root exudates to emit signals to microorganisms. Thus, it is essential a nitrogen supplementation that allows good development of plant, without harming BNF, since the movement of microorganisms towards the roots occurs when there is biochemical recognition (chemotaxis), that is, the emission of signals by plants to microorganisms. Canellas et al. (2013), also observed increase in chlorophyll content of corn plants when inoculated

Table 3. Effect of nitrogen fertilization and inoculation with *Azospirillum brasilense* and *Herbaspirillum seropedicae* on the nutrient content (g kg^{-1} for macronutrients and mg g^{-1} for micronutrients) of corn leaves during flowering stage. Dourados-MS, Brazil (2012).

Treatments	N	P	K	Ca	Mg	S	Zn	Cu	Fe	Mn
	(g kg^{-1})						mg g^{-1}			
1. Control	32.20 ^{b}	3.23 ^{c}	17.98 e	1.90	0.56	1.34	13.34 ^{ab}	8.99	296.67	40.67
2. *A.^{b}rasilense*	40.44 ^{ab}	3.48 ^{bc}	21.20 ^{c}de	2.02	0.65	1.15	13.20 ^{ab}	9.24	292.34	42.19
3. *H. seropedicae*	39.69 ^{ab}	3.92 ^{ab}	20.71 de	2.00	0.61	1.29	13.03 ^{ab}	9.27	255.87	39.09
4. 30 kg ha^{-1} N	39.94 ^{ab}	4.02 ^{ab}	25.91 ^{ab}	2.10	0.64	1.40	12.85 ^{ab}	9.77	215.41	49.65
5. *A.^{b}rasilense* + 30 kg ha^{-1} N	40.69 ^{ab}	3.52 ^{bc}	24.51 ^{bc}d	2.21	0.62	1.33	11.09 ^{b}	8.60	289.84	46.41
6. *H. seropedicae* + 30 kg ha^{-1} N	37.69 ^{ab}	4.24 ^{a}	25.75 ^{ab}	2.17	0.71	1.26	12.31 ^{ab}	8.57	202.62	45.93
7. 30 kg ha^{-1} N + 90 kg ha^{-1} N	45.43 ^{ab}	4.21 ^{a}	26.24 ^{ab}	1.97	0.64	1.14	13.45 ^{ab}	9.64	266.28	53.05
8. *A. ^{b}rasilense* + 120 kg ha^{-1} N	49.18 ^{a}	3.91 ^{ab}	25.33 ^{abc}	1.67	0.53	1.34	14.24 ^{a}	8.98	263.43	47.87
9. *H. seropedicae* + 120 kg ha^{-1} N	42.94 ^{ab}	4.20 ^{a}	29.72 ^{a}	1.89	0.63	1.44	15.14 ^{a}	9.40	285.45	47.98
Average	40.91	3.86	24.15	1.99	0.62	1.30	13.18	9.16	274.21	45.87
Teste F	2.19*	6.64*	13.34*	2.11^{ns}	1.18^{ns}	1.94^{ns}	2.86*	0.78^{ns}	1.50^{ns}	1.79^{ns}
CV (%)	19.28	9.04	9.87	13.83	18.89	13.67	12.46	12.66	13.82	17.88

*e ns– significant 5% probability and non-significant, respectively. Medium followed by the same letter in the columns, do not differ statistically between them by Tukey test, the 5% probability. CV: coefficient of variation.

with *H. seropedicae* in association with humic substances.

The contents of N, P, K and Zn in leaves and N, K, Ca and Mg in grains of corn were positively influenced by nitrogen fertilization and inoculation with diazotrophic bacteria, whereas the contents of Ca, Mg, S, Cu, Fe and Mn in leaves and P, S, Zn, Cu and Fe in grains did not respond to the treatments (Tables 3 and 4). The N contents in corn leaves ranged from 32.20 g kg^{-1} in the control treatment to 49.18 g kg^{-1} in the treatment inoculated with *A. brasilense* + 120 kg ha^{-1} of N, evidencing that the inoculation coupled with 30 kg ha^{-1} of N at sowing + 90 kg ha^{-1} of N in covering increased N content in corn leaves in about 52.73%, compared with the control (without either inoculation or N) (Table 3). The contents of P, K and Zn in the leaves, unlike N content, were higher in the treatment inoculated with *H. seropedicae* + 120 kg ha^{-1} of N. There were increases of 30%, 64.29 and 13.49% in the contents of P, K and Zn, respectively, compared with the control (Table 3). These results suggest that inoculation with these diazotrophic bacteria associated with nitrogen fertilization increases N, P, K and Zn contents in corn leaves and that inoculation can contribute to improving the use of N-fertilizers by the plant (Dobbelaere et al., 2003).

Dobbelaere et al. (2001) observed increase in N, P, and K contents of corn leaves when working with bacteria from the genus *Azospirillum.* Francisco et al. (2012) found increase in Zn concentrations of corn leaves when inoculated with *A. brasilense* and supplied with 30 kg ha^{-1} of N. Hungria et al. (2010) observed higher leaf contents of N, P, Zn and Cu in corn plants inoculated with *Azospirillum* spp. Bashan et al. (2004) and Alves (2007) also reported increase in nutrient contents of plants inoculated with diazotrophic bacteria.

This higher absorption of nutrients N, P, K and Zn, by roots can occur as a result of the production of growth-promoting substances by bacteria (Baldani and Baldani, 2005), or changes in root architecture (Dobbelaere et al., 1999), which allows better exploration of soil and increases plant's capacity to absorb nutrients (Creus et al., 2004). Besides, it can be attributed to nitrogen fertilization and to solubilization of zinc phosphates and oxides by bacteria (Baldotto et al., 2010).

Regarding the contents of N and K in corn grains, the inoculation with *A. brasilense* without nitrogen fertilization promoted higher accumulation in grains, statistically differing from the treatments with inoculation coupled with nitrogen fertilization (Table 4). The inoculation with *A. brasilense* promoted average increases in N and K grain contents of approximately 25.47 and 72.35%, respectively, compared with the

Table 4. Effect of nitrogen fertilization and inoculation with *Azospirillum brasilense* and *Herbaspirillum seropedicae* on the nutrient contents (g kg^{-1} for macronutrients and mg g^{-1} for micronutrients) of corn grains. Dourados-MS, Brazil (2012).

Treatments	N	P	K	C^{a}	Mg	S	Zn	Cu	Fe	Mn
	(g kg^{-1})						(mg g^{-1})			
1. Control	18.72 ^{ab}	5.48	4.34 ^{ab}	0.32 ^{ab}	1.14 ^{a}	0.69	13.71	1.50	51.53	1.71
2. *A.brasilense*	19.99 ^{a}	4.88	4.92 ^{a}	0.34 ^{a}	1.01 ^{a}	0.63	13.26	0.49	41.90	1.68
3. *H. seropedicae*	15.47 ^{bc}	4.86	3.76 ^{ab}	0.24 ^{bc}	0.93 ^{a}	0.61	13.30	0.72	41.96	1.67
4. 30 kg ha^{-1} N	15.97 ^{bc}	4.90	4.26 ^{ab}	0.17 ^{c}	0.54 ^{b}	0.68	14.90	0.78	39.21	2.06
5. *A.brasilense* + 30 kg ha^{-1} N	12.48 ^{c}	4.52	4.01 ^{ab}	0.21 ^{c}	0.48 ^{b}	0.76	13.99	0.83	54.50	1.79
6. *H. seropedicae* + 30 kg ha^{-1} N	14.48 ^{bc}	5.07	3.76 ^{ab}	0.18 ^{c}	0.53 ^{b}	0.78	12.22	1.46	30.62	1.71
7. 30 kg ha^{-1} N + 90 kg ha^{-1} N	15.47 ^{bc}	5.26	3.51 ^{b}	0.20 ^{c}	0.60 ^{b}	0.72	13.54	2.06	22.48	1.98
8. *A. brasilense* + 120 kg ha^{-1} N (30+90)	15.47 ^{bc}	5.40	3.59 ^{b}	0.35 ^{a}	1.06 ^{a}	0.73	10.17	2.24	42.16	2.02
9. *H. seropedicae* + 120 kg ha^{-1} N (30+90)	14.98 ^{bc}	5.56	3.59 ^{b}	0.36 ^{a}	1.10 ^{a}	0.76	10.02	2,34	47.62	2.05
Average	16.36	5.10	3.97	0.26	0.82	0.70	12.74	1.38	41.33	1.85
Teste F	7.94*	1.56^{ns}	3.12*	15.17*	17.37*	8.96^{ns}	11.15^{ns}	8.01^{ns}	1.87^{ns}	8.95 ^{ns}
CV (%)	17.84	13.21	16.05	17.80	19.64	8.27	13.02	79.17	43.03	20.40

* e ns– significant 5% probability and non-significant, respectively. Medium followed by the same letter in the columns, do not differ statistically between them by Tukey test, the 5% probability. CV: coefficient of variation.

treatments inoculated and fertilized with 30 and 120 kg ha^{-1} of N, not differing statistically from the control. These results corroborate those found by Rodrigues et al. (2006) and Pedraza et al. (2009), who verified significant increase in N content of wheat and rice grains with the inoculation of A*zospirillum* spp., without N addition. Guimarães (2006) observed increases in N accumulation in grains of 64% of rice plants (variety IR 42) inoculated with the ZAE 94 strain and fertilized with 50 kg ha^{-1} of N, compared with the control treatment, with no inoculation or fertilization.

The contents of Ca, Mg and Mn were higher when plants were inoculated with *A. brasilense* and *H. seropedicae*, both without nitrogen fertilization and in combination with the highest N dose (120 kg ha^{-1} of N), not differing statistically from each other. The inoculation with diazotrophic bacteria and nitrogen fertilization promoted an improvement in the quality of corn grains for trading, with an increase in protein content, which allows obtaining better grains from a nutritional perspective. Results found by Hungria et al. (2010) suggest that inoculation with *Azospirillum* spp. promotes small increases in the contents of P, K, Mg, S, Zn, Mn and Cu of corn grains, which often may not differ from the control treatment.

Conclusions

Nitrogen fertilization associated with inoculation of *A. brasilense* and *H. seropedicae* positively influenced ear weight, ear diameter, number of grains per ear, shoot dry weight, productivity and chlorophyll content of corn plants. N, P, K and Zn leaf contents increased with nitrogen fertilization and the inoculation with *A. brasilense* and *H. seropedicae*. The inoculation with *A. brasilense* without nitrogen fertilization promoted higher accumulations of N, K, Ca and Mg in the grains compared with the treatments inoculated with *A. brasilense* and *H. seropedicae* and fertilized with 30 and 120 kg ha^{-1} of N. The inoculation with *A. brasilense* or *H. seropedicae* associated with nitrogen fertilization can lead to a reduction in the use of synthetic nitrogen fertilizers in corn cultivations.

Conflict of Interest

The authors have not declared any conflict of interest.

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REFERENCES

Alves GC (2011). Study of interaction of bacterium *herbaspirillum seropedicae* br11417 with plants of maize. Rio de Janeiro: UFRRJ. 52 p. Thesis (doctorate) – agronomy graduate course, concentration area: soil science, federal rural university of Rio de Janeiro, Seropédica.

Alves GC (2007). Effect of inoculation of diazotrophic bacteria of the genera *Herbaspirillum* and *Burkholderia* on genotypes of maize. Rio de Janeiro: UFRRJ, p. 53 Dissertation (master) – agronomy graduate course, concentration area: soil science, federal rural university of Rio de Janeiro, Seropédica.

Baldani JL, Baldani VLD (2005). History on the biological nitrogen fixation research in graminaceous plants: special emphasis on the brazilian experience. Anais da acad. Braz. Sci. 77(3):549-579.

Baldotto LEB, Baldotto MA, Olivares FL, Pio Viana A, Bressan-Smith R. (2010). Selection of growth-promoting bacteria for pineapple 'vitória' during acclimatization. Braz. J. Soil Sci. 34:349-360.

Bashan Y, Holguin G, De-Bashan LE (2004). *Azospirillum* plant relations physiological, molecular, agricultural, and environmental advances (1997-2003). Can. J. Microbiol. 50:521-577.

Braccini AL, Dan LGM, Piccinin GG, Albrecht LP, Barbosa MC (2012). Seed inoculation with *Azospirillum brasilense*, associated with the use of bioregulators in maize. Res. Caat. 25(2):58-64.

Brazilian agricultural research corporation - embrapa. National center for soil research. (2013). Brazilian soil classification system. 3 ed. Rev. Exp.- Brasília, DF: Embrapa soils. P. 353.

Brazilian agricultural research corporation – embrapa. (2009). Manual of chemical analysis of soils, plants and fertilizers. 2 ed. Brasília, df: embrapa, P. 627.

Booij R, Valenzuela JL, Aguilera C (2000). Determination of crop nitrogen status using non invasive methods. In: Haverkort, A.J.; Mackerron, D.K.L. (eds.). Management of nitrogen and water in potato production. The netherlands, wageningen pers. pp. 72-82.

Canellas LP, Balmori DM, Médici LO, Aguiar NO, Campostrini E, Rosa RCC, Façanha AR, Olivares FL (2013). A combination of humic substances and *Herbaspirillum seropedicae* inoculation enhances the growth of maize (*Zea mays* L.). Plant Soil 366:119-132.

Creus CM, Sueldo RJ, Barassi CA (2004). Water relations and yield in *Azospirillum* inoculated wheat exposed to drought in the field. Can. J. Bot. 82:273-281.

Dalla Santa OR, Dalla Santa HS, Fernandéz R, Michelena G, Junior PR, Soccol CR (2008). Influence of *Azospirillum sp*. Inoculation in wheat, barley and oats. Amb. 4(2):197-207.

Dalla santa OR, Soccol CR, Junior PR, Hernández RH, Alvarez GLM, Dalla Santa HS, Pandey A (2004). Effects of inoculation of *Azospirillum sp*. In maize seeds under field conditions. Food, Agric. Environ. 2(1):238- 242.

Dobbelaere S, Vanderleyden J, Okon Y (2003). Plant growth-promoting effects of diazotrophics the rhizosphere. CRC Crit. Rev. Plant Sci. 22(2):107-149.

Dobbelaere S, Croonenborghs A, Tryss A, Ptacek D, Okon Y, Wanderleyden J. (2002). Effect of inoculation with wild type *Azospirillum brasilense* and *Azospirillum irakenses* trains on development and nitrogen uptake of spring wheat and grain maize. Biol. Fert. Soils 36(4):284-297.

Dobbelaere S (2001). Response of agronomically important crops to inoculation with *Azospirillum*. Aust. J. Plant Physiol. 28(9):871-879.

Dobbelaere S, Croonenborghs A, Thys A, Broek A V, Anderleyden J (1999). Phytostimulatory effect of *azospirillum brasilense* wild type and mutant strains altered in iaa production on wheat. Plant Soil 212:155-164.

Dotto AP, Lana MC, Steiner F, Frandoloso JF (2010). Maize yield in response to *Herbaspirillum seropedicae* inoculation under different nitrogen levels. Braz. J. Agric. Res. 5(3):376-382.

Ferreira DF (2000). Variance analysis system for balanced data. Lavras: Ufla.

Ferreira JS, Guimarães SL, Baldani VLD (2011). Rice grain production inoculated with *Herbaspirillum seropedicae*. Encicl. Biosf. J. 7(3):826-833.

Ferreira JS, Baldani JI, Baldani VLD (2010). Selection of peat inoculants with diazotrophic bacteria in two rice varieties. Acta Sci. Agron. 32(1):179-185.

Francisco EAB, Kappes C, Domingues L, Felippi CL (2012). Inoculation of corn seeds with *Azospirillum brasilense* and application of nitrogen in covering. In: XXIX national corn and sorghum congress, águas de lindóia, annals...águas de Lindóia.

García de Salamone IE, Dobereiner J, Urguiaga S, Boddey RM (1996). Biological nitrogen fixation in *Azospirillum* strain maize genotype associations as evaluated by the ^{15}n isotope diluition technique. Biol. Fert. Soils 23(3):249-256.

Guimarães FV, Pinto Junior AS, Offemann LC, Rodrigues LFOS, Klein J, Inagaki AM, Pozzebom W, Diamante MS, Bulegon LG, Bellé RF, Costa ACPR (2012). Production components of the corn hybrid 30f53h inoculated with the strains ab-v5 and ab-v6 of the bacterium *Azospirillum brasilense*. In: XXIX national corn and sorghum congress, águas de lindóia, annals...águas de Lindóia.

Guimarães SL, Baldani JI, Baldani VLD, Jacob-Neto J (2007). Addition of molybdenum in peat inoculum with diazotrophic bacteria used in two rice cultivars. Braz. J. Agric. Res. 42(3):393-398.

Guimarães SL (2006). Application of peat inoculant with diazotrophic bacteria and molybdenum in rice cultivars fertilized with mineral nitrogen. P. 88. Thesis (doctorate) – agronomy graduate course, concentration area: crop science, federal rural university of Rio de Janeiro, Seropédica.

Huergo LF, Monteiro RA, Bonatto AC, Rigo LU, Steffens MBR, Cruz LM, Chubatsu LS, Souza EM, Pedrosa FO (2008). Regulation of nitrogen fixation in *Azospirillum brasilense*. In: Cassán, F.D.; Garcia de Salamone, I. *Azospirillum sp*.: cell physiology, plant interactions and agronomic research in Argentina. Asociación argentina de microbiologia, argentina. pp. 17-35.

Hungria M (2011). Inoculation with *Azospirillum brasilense*: innovation in yield at low cost. Londrina: Embrapa soybean. P. 36.

Hungria M, Campo RJ, Souza EM, Pedrosa FO (2010). O. Inoculation with selected strains of *A. brasilense* and *A. lipoferum* improves yields of maize and wheat in brazil. Plant Soil 331(1-2):413-425.

Hungria M, Campo RJ, Mendes IC, Graham PH (2006). Contribution of biological nitrogen fixation to the n nutrition of grain crops in the tropics: the success of soybean (*Glycine max* (L.) Merr.) In south america. In: Singh, R. P.; Shankar, N.; Jaiwal, P. K. (ed.). Nitrogen nutrition and sustainable plant productivity. Houston: Studium press, llc, pp. 43-93.

Kappes C, Arf O, Arf MV, Ferreira JP, Dal Bem EA, Portugual JR, Vilela RG (2013). Inoculation of seeds with diazotrophic bacteria and nitrogen foliar and top dressing application in corn. Semina: Agric. Sci. 34(2):527-538.

Kennedy IR, Choudhury ATMA, Kecskés ML (2004). Non-symbiotic bacterial diazotrophs in crop-farming systems: can their potential for plant growth promotion be better exploited. Soil Biol. Biochem. 36(8):1229-1244.

Kolb W, Martin P (1987). Response of plant roots to inoculation with *Azospirillum brasilense* and to application of indolacetic acid. In: klingmuler, w. *Azospirillum* III: genetics, phisiology, ecology. Berlin: ed. Springer. pp. 215-221.

Lana MC, Dartora J, Marini M, Hann JE (2012). Inoculation with *Azospirillum*, associated with nitrogen fertilization in maize. J. Ceres. 59(3):399-405.

Malavolta E, Vitti GC, Oliveira SA (1997). Evaluation of plant nutritional state: principles and applications. 2 ed. Piracicaba: potafos. 319 pp.

Pedraza RO, Bellone CH, Bellone SC, Boa Sorte PMF, Teixeira RS (2009). *Azospirillum* inoculation and nitrogen fertilization effect on grain yield and on the diversity of endophytic bacteria in the phyllosphere of rice rainfed crop. Eur. J. Soil Biol. 45:36–43.

Perin L, Martinez-Aguilar L, Paredes-Valdez G, Baldani JL, Estrada-de Los Santos P, Reis VM, Caballero-Mellado J (2006). *Burkholderia silvatlantica* sp. Nov., a diazotrophic bacterium associated with sugar cane and maize. Int. J. Syst. Evol. Microbiol. 56(8):1931-1937.

Quadros PD (2009). Inoculation of *Azospirillum spp*. In seeds of maize cultivars cropped in south brazil. Porto alegre: ufrgs. Dissertation (master) – agronomy graduate course, concentration area: soil science, federal university of Rio Grande do Sul, Porto Alegre. 63 pp.

Reis Júnior FB, Machado CTT, Machado AT, Sodek I (2008) . Inoculation of *Azospirillum amazonense* in two maize genotypes under different n treatments. Braz. J. Soil Sci. 32(3):1139-1146.

Reis Jr. FB, Silva MF, Teixeira KRS, Urquiaga S, Reis VM (2004). Identification of *Azospirillum amazonense* isolates associated to *brachiaria* spp. At different stages and growth conditions, and bacterial plant hormone production. Braz. J. Soil Sci. 28(1):103-113.

Rodrigues IS, Baldani VLD, Reis VM, Baldani JL (2006). Diversity of endophytic diazotrophic bacteria of the genus *Herbaspirillum* and *burkholderia* in wetland rice. Braz. J. Agric. Res. 41(2):275-284.

Salomone G, Döbereiner J (1996). Maize genotypes effects on the response to *Azospirillum* inoculation. Biology fertilizer soils. 21:193-196.

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Soil physical attributes under different grazing management of winter forage crops in crop-livestock system at Southern Brazil

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The effects of different species and grazing management of winter forage crops on the physical properties of a clayey Red Latosol of the western region of Parana State under crop-livestock integration systems were investigated in the present study. Treatments consisted of three different winter crops [white oat (*Avena sativa*), dual-purpose wheat (*Triticum aestivum*) and triticale (X *Tritico secale*)] and three grazing management (one and two grazing with 15 cm of residue height, and without grazing), followed by soybean cultivation, in a randomized block design. Undisturbed soil samples were collected at 0.00-0.10 and 0.10-0.20 m depths, after the winter crops harvest (October/2012) and soybean harvest (March/2013) and was determined the soil bulk density until 0.35 cm depth. The soil macroporosity in the 0.00-0.10 and 0.10-0.20 m soil layers and the total soil porosity in the 0.10-0.20 m layer, after winter crops harvest, were influenced by the crops and management of winter forage. In the evaluation performed after the soybean harvest, there were changes in the soil macroporosity in the 0.0-0.10 m layer and for microporosity and total soil porosity in the 0.10-0.20 m soil layer. The soil bulk density was not affected by the crops and management of winter forage. The different species and grazing management of winter crops in integrated crop-livestock systems promoted changes in soil penetration resistance in the 0.20-0.30 m soil layer. The cultivation of white oat during winter and management with two grazing resulted in lower soil penetration resistance levels.

Key words: Physical quality, soil structure, soil penetration resistance, conservation cropping systems.

INTRODUCTION

Integrated crop-livestock systems (ICLS) could provide opportunities to capture ecological interactions among different land use systems to make agricultural ecosystems more efficient at cycling nutrients, preserving natural resources and the environment, improving soil quality, and enhancing biodiversity (Lemaire et al., 2013). Moreover, diversifying agricultural production could utilize labor more efficiently at farm and/or regional scales (Hoagland et al., 2010). However, depending of management system that the soil is subjected, the ICLS

Table 1. Soil chemical attributes and particle size at the beginning of the experiment.

Depth (m)	pH	O.M.	P	H+Al	K	Ca	Mg	CEC	V	Textural		
										Clay	Silt	Sand
		g kg^{-1}	mg kg^{-1}	---------------- $cmol_c$ kg^{-1} ----------------					%	------- g kg^{-1} -------		
0.0–0.10	4.5	32.6	24.5	9.40	0.53	4.56	1.54	16.02	42	680	265	55
0.10–0.20	4.6	32.6	25.9	8.62	0.44	5.32	1.67	16.04	46	750	200	50
0.20–0.30	4.8	32.5	12.1	7.47	0.25	5.49	1.75	14.95	50	705	240	55

pH in $CaCl_2$ 0.01 M. O.M.: organic matter. P and K: Mehlich-1. H+Al: pH SMP (7,5). Ca and Mg: KCl 1 mol L^{-1}. CEC: cation exchange capacity. V: soil base saturation.

can lead to soil degradation or recovery of its structure, this because chemical, physical and biological attributes are continually interacting.

In Brazil southern, there is high potential for milk and beef production in annual winter pastures (white and black oat, dual-purpose wheat and annual ryegrass) (Balbinot et al., 2009). Additionally, the appropriate animal grazing during the winter, ICLS can result in the increase in nutrients cycling particularly nitrogen and maize yield (Silva et al., 2012). However, issues surrounding the soil-plant-animal system are not yet well understood, implying for more research with different forages species and agricultural crops, and pasture systems (Balbinot et al., 2009).

The presence of the animal cause amendments on sustainability and production capacity, as well as in functioning of the system, that depending on the grazing intensity is able of determine the animal production, soil conditions and the amount of straw that is transferred to the agricultural phase (Balbinot et al., 2009). The presence of animals in the appropriate amount does not affect both the production of forage biomass in winter and subsequent crop yields. However, overcrowding of animals grazing can cause changes on the physical properties, particularly in the surface soil compaction (Araújo et al., 2008) and content of soil organic matter, affecting the root growth (Souza et al., 2009) and crop yields cultivated after grazing (Albuquerque et al., 2001). The study of the changes resulting from the soil use and managements is of great importance for the adoption of management systems more compatible with the characteristics of each region and soil (Rozane et al., 2010), providing less impact on native soil characteristics. Soil attributes such as soil bulk density (Balbino et al., 2004), macroporosity, microporosity and total soil porosity (Karlen and Stott, 1994), has been frequently used as indicators of soil physical quality, mainly due to low cost and facility of obtaining measurements (Schiavo and Colodro, 2012). In addition, the soil penetration resistance of the soil has been used to identify compacted layers (Cunha et al., 2002).

Considering the risk of soil compaction on ICLS and the lack of information about the recommendations for the proper management of winter pastures, was idealized this study to evaluate the effects of different species and management of winter forage crops on the physical properties of a clayey Red Latosol of the western region of Paraná State under crop-livestock integration systems.

MATERIALS AND METHODS

The experiment was carried out in Marechal Cândido Rondon, Paraná, Brazil, on a clayey Rhodic Hapludox (Red Latosol in the Brazilian classification), in an area (24° 31' 58" S, 54° 01' 10" W, altitude of 400 m) where soybean/wheat/corn had been sown in no-till rotation as of 2008. Before starting the experiment (autumn-winter 2012), the soil was sampled for chemical and physical analysis (Embrapa, 1997) up to 0.30 m (Table 1). The regional climate, according to Köppen's Cfa type mesothermal humid subtropical dry winter, with well distributed during rains and hot summers. The 30 years mean annual temperature is 21.4°C with a July minimum of 14.7°C and a January maximum of 28.6°C, and mean annual precipitation of 1,500 mm. Rainfall and temperature data gathered during the experiment are shown in Figure 1.

The experimental design was a split-plot in randomized blocks with four replicates. In the A bands, were established the three winter crops (that is, white oat, dual-purpose wheat and triticale) and the different management of winter crops (started when the winter crops reached 35 cm) was established as B bands. Management regimes of winter crops investigated were: (i) one grazing with 15 cm of residue height; (ii) two grazing with 15 cm of residue height; and (iii) without grazing. The A bands were 10.0 × 15.0 m, the B bands were 5.0 × 30.0 m, and 10.0 x 5.0 the experimental plots. Before the establishment of the experiment, 4.2 Mg ha^{-1} of lime was applied on the soil surface to elevate the soil base saturation to 70%. Experimental area was desiccated with glyphosate (1.20 kg ha^{-1} a.i.) at a spray volume of 250 L ha^{-1}. Thirty days after the desiccation, winter crops were sown. White oat (cv. IPR 126), dual-purpose wheat (cv. BRS Tarumã) and triticale (cv. IPR 111) were sown in April 19, 2012 in 0.17 m spaced rows at densities of 60, 90 and 50 kg seeds ha^{-1}, respectively. The fertilization was carried out by applying 200 kg ha^{-1} 08-20-20 formulation at sowing, and 120 kg ha^{-1} N topdressing as urea (spitted after management of winter crops).

The management of winter crops was initiated when plants had 25 to 35 cm of height. For the grazing, nine Holstein cows with mean body weight of 663±52.4 kg were used. Cows remained in

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subplots for four hours daily (two in the morning and two in the afternoon period) or until desired height of 15-20 cm, not to damage the apical meristem.

Soybean [*Glycine max* L. (Merrill), cv. BMX Potência RR] was cropped in the summer (November through March) in all the plots under crop residues of winter crops. Soybean was sown in rows spaced 0.45 m with 14 seeds m^{-1}, fertilized with 350 kg ha^{-1} 02-20-20 formulation, applied in the seed furrows. After the winter crops harvest (October 2012) and soybean harvest (March 2013), undisturbed soil samples were collected at 0.00-0.10 and 0.10-0.20m depths from each experimental unit, using a 90.5 cm^3 cylindrical sampler, to determine soil bulk density (BD), macroporosity (Ma) and microporosity (Mi) by the tension table method (Embrapa, 1997), and total soil porosity (TSP) by summing the values for macro- and microporosity.

Soil penetration resistance (PR) down to the 0.35 m depth was established in three points per experimental unit using an impact penetrometer (model STOLF; base diameter 13.0 mm, angle 60°). The calculations were made in line with Stolf (1991), and the results presented in MPa. Original data were submitted to analysis of variance and the results of different winter crops and management of grazing were compared using the Tukey test ($p < 0.05$). All analyses were performed using Sisvar 5.1 software for Windows (Statistical Analysis Software, UFLA, Lavras, MG, BRA).

RESULTS AND DISCUSSION

Total soil porosity (TSP), macroporosity (Ma), microporosity (Mi) and soil bulk density (BD)

After harvest of winter crops, the results for soil porosity in the 0.00 to 0.20 m soil layer under the different management of winter crops (Table 2) showed that for the Ma, there was significant interaction between the factors studied. For the TSP, in the 0.10-0.20 m soil layer there was significant difference in grazing management of winter crops (Table 2). Different species and management of winter forage crops did not affect the Mi, BD and TPS in the 0.00-0.10 m layer (Table 2). In the evaluation performed after the soybean harvest data showed that there was significant interaction between the winter crops and grazing management for the Ma in the 0.00-0.10 m layer, and for Mi and TSP in the 0.10 to 0.20 m soil layer (Table 3). Soil physical attributes were not affected by the isolated effect of the experimental treatments (Table 3).

In general, the results observed for the physical attributes (Tables 2 and 3) soil layers studied are consistent with results reported by other authors as Flores et al. (2007) who studied the changes introduced by animal trampling on soil physical properties and the changes resulting from this trampling influence on the establishment and yield of soybean, already Spera et al. (2009) studied the effect of grain production and grazing winter annual and perennial pasture systems under no-tillage system, after ten years of cultivation on soil physical properties and confirm the small magnitude of the changes caused by adequate animal trampling. These small changes, when present, does not reach critical levels for the root growth of crops grown in succession, since the pressure applied by the animal paws is not greater than the soil resistance to plastic deformation (Conte et al., 2011).

It was expected that in the management with two grazing of winter crops there were changes on soil physical attributes. In ICLS, changes in physical properties can occur in the surface layer, more or less intensely, due to animal trampling that depends upon the intensity and frequency of pasture (Flores et al., 2007). The great magnitude of these changes is connected to the management that is applied to areas under pasture grazing, which may vary according to texture, organic matter content, soil water content, species of plants, pasture intensity and pasture grazing time and also animal species and category (Flores et al., 2007; Lanzanova et al., 2007; Defossez and Richard, 2002). In part, the absence of changes on the soil physical properties was due to the grass species used in this study. According to Albuquerque et al. (2001), in ICLS, the presence of forage grass roots improve soil structure, mitigating the impact of animal trampling, as a result of vigorous root systems and soil descompaction of forage plants (Castagnara et al., 2012). After the harvest of winter crops, the highest Ma values were found for white oat and dual-purpose wheat, in the 0.00-0.10 m soil layer, when these crops were subjected to the one and two grazing, respectively (Table 2). In the 0.10 to 0.20 m soil layer, the highest Ma values were verified for white oat and dual-purpose wheat subjected to the grazing, and for triticale, when this crop was not grazed (Table 2).

In the evaluation after soybean harvest, the cultivation of triticale during the winter without grazing provided the highest amount of macropores in the 0.00 to 0.10 m soil layer compared to the wheat crop (Table 3), while the cultivation of white oats provided intermediate Ma. Growing plants with vigorous root system is important in developing a net of biopores in the soil profile (Williams and Weil, 2004), and this feature can affect the amount of soil macropores. Calonego and Rosolem (2010) verified that soybean root growth in the soil profile was increased under rotation with triticale due to the presence of biopores and a decrease in soil penetration resistance.

The Ma values ranged from 0.06 to 0.10 m^3 m^{-3}, and are situated in the range considered optimal for the proper development of plants which varies from 0.07 to 0.17 m^3 m^{-3} (Drewry et al., 2008). Macroporosity is a of soil properties more susceptible to changes imposed by soil management (Spera et al., 2012). In general, the absence of soil disturbance can induce to soil compaction and reductionof Ma. However, the low soil moisture during grazing (Figure 1), combined with the ability to soil restructure in over time, may have contributed to this result. Flores et al. (2007) investigating changes in the soil physical properties promoted by animal treading, verified that the soil density and compressibility were higher and the porosity lower in the grazed areas, compared to non-grazed. The increase of macropores on

Table 2. Soil physical attributes at 0.0-0.10 and 0.10-0.20 m depths under different management of winter crops. Measurements were taken after harvest of winter crops (October, 2012).

Crop	Management of winter crops							
	One grazing	Two grazing	No grazing	Mean	One grazing	Two grazing	No grazing	Mean
	Macroporosity (m^3 m^{-3}) (0.0–0.10 m)				**Macroporosity (m^3 m^{-3}) (0.10–0.20 m)**			
Oat	0.09^{aA}	0.07^{bA}	0.08^{aA}	0.08	0.08^{aA}	0.07^{aA}	0.05^{bB}	0.07
Wheat	0.06^{bA}	0.10^{aA}	0.08^{aA}	0.08	0.09^{aA}	0.07^{aB}	0.05^{bB}	0.07
Triticale	0.06^{bA}	0.07^{bA}	0.08^{aA}	0.07	0.06^{bA}	0.05^{bA}	0.07^{aA}	0.06
Mean	0.07	0.08	0.08		0.07	0.06	0.06	
	Microporosity (m^3 m^{-3}) (0.0–0.10 m)				**Microporosity (m^3 m^{-3}) (0.10–0.20 m)**			
Oat	0.46	0.45	0.47	0.46	0.45	0.46	0.46	0.46
Wheat	0.47	0.45	0.47	0.47	0.45	0.43	0.45	0.44
Triticale	0.47	0.45	0.46	0.46	0.46	0.46	0.45	0.46
Mean	0.47	0.45	0.47		0.45	0.45	0.45	
	Total soil porosity (m^3 m^{-3}) (0.0–0.10 m)				**Total soil porosity (m^3 m^{-3}) (0.10–0.20 m)**			
Oat	0.55	0.52	0.55	054	0.53	0.53	0.51	0.52
Wheat	0.53	0.55	0.56	0.55	0.54	0.50	0.50	0.51
Triticale	0.53	0.52	0.54	0.53	0.52	0.51	0.51	0.51
Mean	0.54	0.53	0.55		0.53**A**	0.51**B**	0.51**B**	
	Soil bulk density (Mg m^{-3}) (0.0–0.10 m)				**Soil bulk density (Mg m^{-3}) (0.10–0.20 m)**			
Oat	1.21	1.31	1.24	1.25	1.32	1.28	1.31	1.30
Wheat	1.36	1.19	1.18	1.24	1.26	1.29	1.29	1.28
Triticale	1.30	1.24	1.18	1.24	1.33	1.37	1.27	1.32
Mean	1.29	1.25	1.20		1.30	1.31	1.29	

Values represented by the different lower case letters in the column and upper case letters in the lines, show significant differences (Tukey test, $p < 0.05$).

the ICLS is important for the conservation of soil and water, because it is directly related to improve of aeration and water infiltration into the soil (Schiavo and Colodro, 2012).

Regarding Mi, the cultivation of triticale during winter provided the highest values in the 0.10–0.20 m soil layer, after soybean harvest, when this crop was subjected to the two grazing (Table 3). Investigating different ICLS, Spera et al. (2009) found that animal trampling increased soil Mi and decreased Ma and TSP, however, without reaching levels capable of causing soil degradation. Soil compaction resulting from animal trampling during grazing can increase the BD and Mi and decrease Ma and TSP (Spera et al., 2004).

The Mi values ranged from 0.44 to 0.50 m^3 m^{-3}, and are above the value considered optimal for the proper development of plants, which is, 0.33 m^3 m^{-3} (KiehL, 1979). These results were expected, because according to Viana et al. (2011), the Mi is inversely proportional to the soil Ma. The management of winter crops with one grazing resulted in the higher TSP value in the 0.10-0.20 m soil layer, in evaluation performed after the winter crops harvest (Table 2). After soybean harvest, the highest TSP values, in the 0.10 to 0.20 m soil layer, were found for triticale and white oat, when these crops were subjected to the two grazing and without grazing, respectively (Table 3). According to Bertol et al. (2004), the soil porosity is influenced by soil management based on changes in soil bulk density. Changes in soil porosity limit nutrient uptake, water infiltration and redistribution, gas exchange and root growth. However, soil attributes present high spatial variability, due to environmental conditions, types and sizes of machines and equipment and systems used crops.

The different species and grazing management of winter crops did not affect the BD (Tables 2 and 3). The BD is a property considered in the evaluation of soil physical quality (Klein and Camara, 2007) because, in ICLS under no-till the increasing BD, when this system is used without technical criteria for pasture management, can cause negative impacts on soil structure and reduce productivity (Costa et al., 2009). The soil compaction caused by animal trampling has been identified as a major cause of degradation of cultivated areas in ICLS (Albuquerque et al., 2001). The BD values ranged from 1.13 to 1.36 Mg m^{-3} (Tables 2 and 3). In an experiment

Table 3. Soil physical attributes at 0.0-0.10 and 0.10-0.20 m depths under different management of winter crops. Measurements were taken after soybean harvest (March 2013).

Crop	Management of winter crops							
	One grazing	Two grazing	No grazing	Mean	One grazing	Two grazing	No grazing	Mean
	Macroporosity ($m^3 m^{-3}$) (0.0–0.10 m)				Macroporosity ($m^3 m^{-3}$) (0.10–0.20 m)			
Oat	0.06^{aA}	0.07^{aA}	0.07^{abA}	0.07	0.06	0.06	0.07	0.06
Wheat	0.06^{aA}	0.07^{aA}	0.05^{bA}	0.06	0.06	0.07	0.06	0.06
Triticale	0.07^{aA}	0.07^{aA}	0.09^{aA}	0.07	0.06	0.07	0.07	0.07
Mean	0.06	0.070	0.07		0.06	0.07	0.07	
	Microporosity ($m^3 m^{-3}$) (0.0–0.10 m)				Microporosity ($m^3 m^{-3}$) (0.10–0.20 m)			
Oat	0.47	0.48	0.50	0.48	0.46^{aAB}	0.44^{bB}	0.48^{aA}	0.46
Wheat	0.50	0.47	0.50	0.49	0.46^{aA}	0.45^{bA}	0.47^{aA}	0.46
Triticale	0.47	0.48	0.46	0.47	0.45^{aA}	0.49^{aA}	0.46^{aA}	0.47
Mean	0.48	0.48	0.49		0.46	0.46	0.47	
	Total soil porosity ($m^3 m^{-3}$) (0.0–0.10 m)				Total soil porosity ($m^3 m^{-3}$) (0.10–0.20 m)			
Oat	0.53	0.55	0.57	0.55	0.52^{aAB}	0.50^{bB}	0.55^{aA}	0.52
Wheat	0.56	0.54	0.55	0.55	0.52^{aA}	0.52^{abA}	0.53^{aA}	0.52
Triticale	0.54	0.55	0.54	0.54	0.52^{aA}	0.55^{aA}	0.52^{aA}	0.53
Mean	0.54	0.55	0.56		0.52	0.53	0.53	
	Soil bulk density ($Mg m^{-3}$) (0.0–0.10 m)				Soil bulk density ($Mg m^{-3}$) (0.10–0.20 m)			
Oat	1.29	1.23	1.12	1.21	1.33	1.33	1.28	1.31
Wheat	1.23	1.21	1.24	1.23	1.30	1.30	1.25	1.28
Triticale	1.27	1.20	1.13	1.20	1.30	1.26	1.27	1.28
Mean	1.26	1.22	1.16		1.31	1.29	1.27	

Values represented by the different lower case letters in the column and upper case letters in the lines, show significant differences (Tukey test, $p < 0.05$).

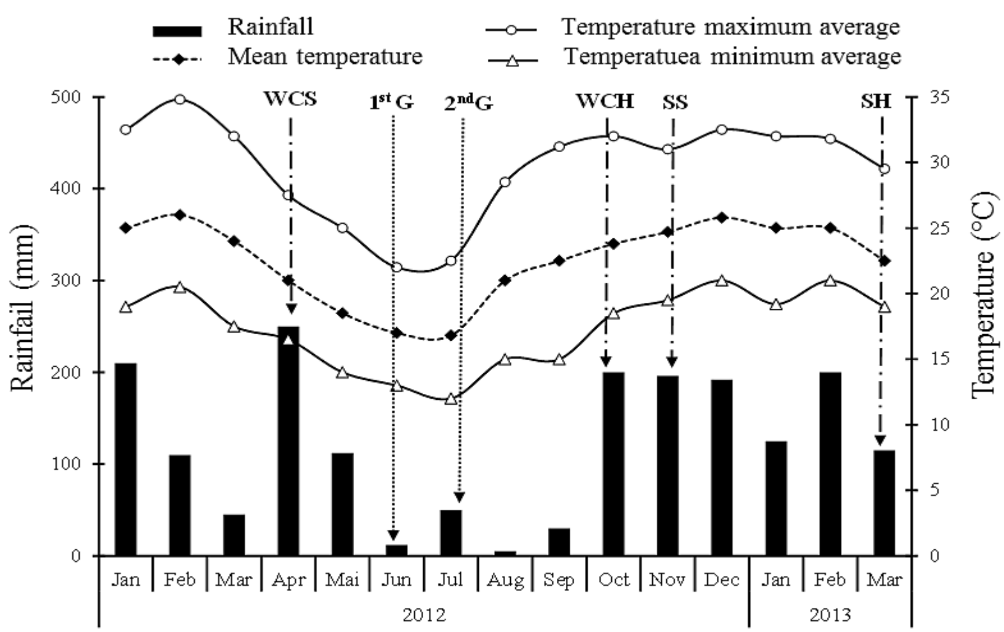

Figure 1. Total monthly rainfall (mm) and monthly average temperature (°C) during the experiment. WCS: winter crops sowing; 1st and 2nd G: first and second grazing; WCH: winter crops harvest; SS: soybean sowing; SH: soybean harvest.

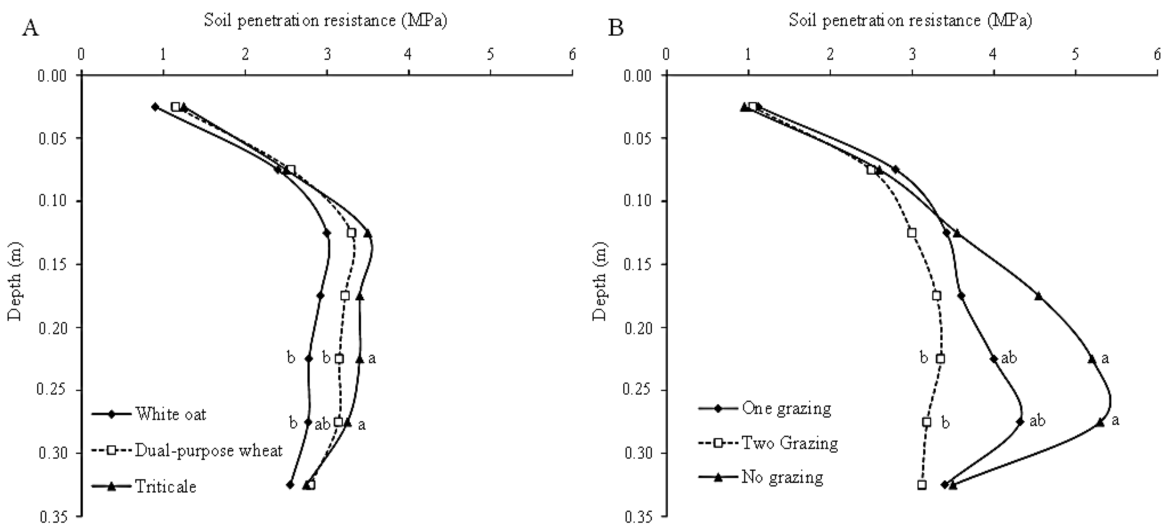

Figure 2. Soil penetration resistance (PR) in soil profile after soybean harvest, as affected by winter crops (A) and grazing management of winter crops (B). Different letters at each depth, show significant differences (Tukey test, $p < 0.05$).

with crop rotation in a Red Nitosol with 590 g kg^{-1} clay, Calonego and Rosolem (2011) found similar BD values from 1.22 to 1.39 Mg m^{-3} to a depth of 0.60 m. In this study, these same authors also determined the critical soil bulk density. During the three years of experiment, the values of the critical bulk density ranged from 1.22 to 1.37 Mg m^{-3}, in the 0.10-0.20 m soil layer. For Klein and Camara (2007), the value considered limiting to the growth of plant roots in clayey Latosols is around 1.40 Mg m^{-3}. Considering these values of critical soil bulk density can be inferred in this study there was no limitation to the plant root growth.

Penetration resistance (PR)

The different species and grazing management of winter crops affect the PR in the 0.20 to 0.25 m and 0.25 to 0.30 m soil layers of profundity (Figure 2). The lower PR values were found for the cultivation of white oat and the highest values for triticale (Figure 2A). For grazing managements, the lowest PR values were found when the winter crops were subjected to two grazing and the highest values when there was no grazing (Figure 2B).

In ICLS under no-till, the grazing intensities influence the stability of large aggregates (> 2 mm), which represent more than 50% of the soil mass (Souza et al., 2010). These large aggregates or stable aggregates are crucial for a good soil structure, providing pore space for root and fauna growth and development and water and air circulation (Salton et al., 2008). Thus, it is found that the greater number of grazing provided less PR, which can improve the development of the culture grown in succession.

The compaction level caused by animal trampling is influenced by several factors; especially the height of pasture management and the amount of plant residue deposited on the soil surface (Braida et al., 2006) and soil moisture. Thus, should emphasize the importance of continuous use of winter forage crops in ICLS under no-till, and the monitoring of the physical conditions of the soil over time, essential for the evaluation of management systems (Costa et al., 2011). Most of the obtained PR values are above 2.0 MPa (Figure 2), value cited by the United States Department of Agriculture (1993) as limiting to the root growth of most cultivated annual crops. Lipiec and Hatano (2003) argue that the PR values ranging from 1.0 to 1.7 MPa begin restricting the plant root growth, and that values between 3.0 and 4.0 MPa paralyze root growth. However, according to Canarache (1990), only PR values above 2.5 MPa impair plant growth, or from 2.0 to 3.0 MPa limited to soybean yield (Beutler et al., 2006).

The importance of determining PR is the correlation with the effect of animal trampling in the ICLS, affecting root growth and the soil physical properties, and is a way of rapidly obtaining results. However, PR is influenced by a number of soil properties such as density, moisture content, water potential, texture, aggregation, cementation, organic matter content and mineralogy. Soil moisture content and bulk density are considered the most significant of these properties (Tavares-Filho et al., 2012).

The PR indicates that evaluations of BD determined in the 0.00 to 0.10 m are suitable for characterizing the effect of animal trampling on soil compaction, since this effect usually restricted to this layer. However, its magnitude is not reflected in the subsequent crop yield to grazing, in this case, soybean crop, which is evaluated annually (Conte et al., 2011). Moreover, the intensity of the damage caused by compaction is directly influenced by the soil water availability and the plant development stage; because the occurrence of low water availability in stages of greater plant growth can cause drastic reductions in plant yields grown in compacted soils (Castagnara et al., 2012). However, as in this study there was no influence of grazing down to the 0.20 m depth, one can use the ICLS without causing negative impacts on soil physical quality for subsequent culture.

Conclusions

Soil porosity in the 0.00 to 0.20 m soil layer in integrated crop-livestock systems under no-till was influenced by the crops and grazing management of winter forage. The different species and grazing management of winter crops in integrated crop-livestock systems did not affect the soil bulk density. The annual winter cereals, managed in no-till with different numbers of grazing, promoted changes in resistance to penetration in the layer 20 to 25 cm and 25 to 30 cm depth.

Conflict of Interest

The authors have not declared any conflict of interest.

REFERENCES

Albuquerque JA, Sangoi L, Ender M (2001). Efeitos da integração lavoura-pecuária nas propriedades físicas do solo e características da cultura do milho. R. Bras. C. Solo 25:717-723. http://www.redalyc.org/pdf/1802/180218337022.pdf

Araújo FS, Salviano AAC, Leite LFC, Leite LFC, Souza ZM, Sousa ACM (2010). Physical quality of a yellow Latossol under integrated crop-livestock system. R. Bras. C. Solo 34:717-723. http://dx.doi.org/10.1590/S0100-06832010000300013

Balbino LC, Bruand A, Cousin I, Brossard M, Quétin P, Grimaldi M (2004). Change in the hydraulic properties of a Brazilian clay Ferralsol on clearing for pasture. Geoderma 120:297-307.

Balbinot Jr AA, Moraes A, Veiga M, Pelissari A, Dieckow J (2009). Integração lavoura-pecuária: intensificação de uso de áreas agrícolas. Ciência Rural 39:1925-1933. http://dx.doi.org/10.1590/S0103-84782009005000107

Bertol I, Albuquerque JA, Leite D, Amaral AJ, Zoldan Jr WA (2004). Propriedades físicas do solo sob preparo convencional e semeadura direta em rotação e sucessão de culturas, comparadas às do campo nativo. R. Bras. C. Solo 28:155-163. http://dx.doi.org/10.1590/S0100-06832004000100015

Beutler NA, Centurion JF, Silva AP, Barbosa JC (2006). Intervalo hídrico ótimo e produtividade de cultivares de soja. R. Bra. Eng. Agríc. Ambiental 10:639-45. http://dx.doi.org/10.1590/S1415-43662006000300015

Braida JA, Reichert JM, Veiga M, Reinert DJ (2006). Resíduos vegetais na superfície e carbono orgânico do solo e suas relações com a densidade máxima obtida no ensaio proctor. R. Bras. C. Solo 30:605-614. http://dx.doi.org/10.1590/S0100-06832006000400001

Calonego JC, Rosolem CA (2010). Soybean root growth and yield in rotation with cover crops under chiseling and no-till. Eur. J. Agron. 33:242-249.

Calonego JC, Rosolem CA (2011). Least limiting water range in soil under crop rotations and chiseling. R. Bras. C. Solo 35:759-771. http://dx.doi.org/10.1590/S0100-06832011000300012

Canarache A (1990). Penetrometer - a generalized semi-empirical model estimating soil resistance to penetration. Soil Till. Res. 16:51-70.

Castagnara DD, Karwatte Júnior N, Zoz T, Piano JT, Rossol CD, Oliveira PSR, Seidel EP (2012). Atributos físicos de Latossolo Vermelho sob pousio ou cultivado com forrageiras tropicais sob pastejo. Biosci. J. 28:150-158.

Conte O, Flores JPC, Cassol LC, Anghinoni I, Carvalho PCF, Levien R, Wesp CL (2011). Evolução de atributos físicos de solo em sistema de integração lavoura-pecuária. Pesq. Agropec. Bras. 46:1301-1309. http://dx.doi.org/10.1590/S0100-204X2011001000026

Costa A, Albuquerque JA, Mafra AL, Silva FR (2009). Propriedades físicas do solo em sistemas de manejo na integração agricultura-pecuária. R. Bras. C. Solo 33(2):235-244. http://dx.doi.org/10.1590/S0100-06832009000200001

Costa MSSM, Pivetta LA, Costa LAM, Pivetta LG, Castoldi G, Steiner F (2011). Atributos físicos do solo e produtividade do milho sob sistemas de manejo e adubações. R. Bra. Eng. Agríc. Ambiental 15:810-815. http://dx.doi.org/10.1590/S1415-43662011000800007

Cunha JPAR, Vieira LB, Magalhães AC (2002). Resistência mecânica do solo à penetração sob diferentes densidades e teores de água. Engenharia na Agric. 10:1-7.

Defossez P, Richard G (2002). Models of soil compaction due to traffic and their evaluation. Soil Till. Res. 67:41-64.

Drewry JJ, Cameron KC, Buchan GD (2008). Pasture yield and soil physical property responses to soil compaction from treading and grazing - a review. Aust. J. Soil Res. 46:237-256.

Empresa Brasileira de Pesquisa Agropecuária – EMBRAPA (1997). Manual de métodos de análises de solos. 2.ed. Rio de Janeiro: Embrapa Solos 212 pp.

Flores JPC, Anghinoni I, Cassol LC, Carvalho PCF, Leite JGDB, Fraga TI (2007). Atributos físicos do solo e rendimento de soja em sistema plantio direto em integração lavoura-pecuária com diferentes pressões de pastejo. R. Bras. C. Solo 31:771-780. http://dx.doi.org/10.1590/S0100-06832007000400017

Hoagland L, Hodges L, Helmers GA, Brandle JR, Francis CA (2010). Labor availability in an integrated agricultural system. J. Sustain. Agric. 34:532-548. http://dx.doi.org/10.1080/10440046.2010.484697

Karlen DL, Stott DE (1994). A framework for evaluating physical and chemical indicators of soil quality. In: Doran, J. W.; Coleman, D. C.; Bezdicek, D. F.; Stewart, B. A. (Ed.). Defining soil quality for a sustainable environment. Soil Science Society of America. pp. 53-72.

Kiehl EJ (1979). Manual de edafologia: relações solo planta. São Paulo: Agronômica Ceres. 262 pp.

Klein VA, Camara RK (2007). Rendimento de soja e intervalo hídrico ótimo em Latossolo Vermelho sob plantio direto escarificado. R. Bras. C. Solo 31:221-227. http://dx.doi.org/10.1590/S0100-06832007000200004

Lanzanova ME, Nicoloso RS, Lovato T, Eltz FLF, Amado TJC, Reinert DJ (2007). Atributos físicos do solo em sistema de integração lavoura-pecuária sob plantio direto. R. Bras. C. Solo 31:1131-1140. http://dx.doi.org/10.1590/S0100-06832007000500028

Lemaire G, Franzluebbers A, Carvalho PCF, Dedieu B (2013). Integrated crop-livestock systems: Strategies to achieve synergy between agricultural production and environmental quality. Agric. Ecosyst. Environ. 190(1):4-8. http://dx.doi.org/10.1016/j.agee.2013.08.009

Lipiec J, Hatano R (2003). Quantification of compaction effects on soil physical properties and crop growth. Geoderma 116:107-136. http://dx.doi.org/10.1016/S0016-7061(03)00097-1

Rozane DE, Centurion JF, Romualdo LM, Taniguchi CAK, Trabuco M, Alves AU (2010). Estoque de carbono e estabilidade de agregados de um Latossolo Vermelho distrófico, sob diferentes manejos. Biosci. J. 26:24-32.

Salton JC, Mielniczuk J, Bayer C, Boeni M, Conceição PC, Fabrício AC, Macedo MCM, Broch DL (2008). Agregação e estabilidade de agregados do solo em sistemas agropecuários em Mato Grosso do

Sul. R. Bras. C. Solo 32:11-21. http://dx.doi.org/10.1590/S0100-06832008000100002
Schiavo JÁ, Colodro G (2012). Agregação e resistência a penetração de um Latossolo Vermelho sob sistema de integração lavoura-pecuária. Bragantia 71:406-412. http://dx.doi.org/10.1590/S0006-87052012005000035
Silva HA, Moraes A, Carvalho PCF, Fonseca AF, Dias CTS (2012). Maize and soybeans production in integrated system under no-tillage with different pasture combinations and animal categories. Rev. Ciência Agron. 43:757-765 2012. http://dx.doi.org/10.1590/S1806-66902012000400018
Souza ED, Costa SEVGA, Anghinoni I, Carvalho PCF, Andriguete M, Cao E (2009). Estoques de carbono orgânico e de nitrogênio no solo em sistema de integração lavoura-pecuária em plantio direto, submetido a intensidades de pastejo. R. Bras. C. Solo, 33:1829-1836. http://dx.doi.org/10.1590/S0100-06832009000600031
Souza ED, Costa SEVGA, Anghinoni I, Lima CVS, Carvalho PDF, Martins AP (2010). Soil microbial biomass in a no-tillage integrated crop-livestock system under different grazing intensities. R. Bras. C. Solo 34:1362-1374. http://dx.doi.org/10.1590/S0100-06832010000100008
Spera ST, Santos HP, Fontaneli RS, Tomm GO (2004). Avaliações de alguns atributos físicos de solo em sistemas de produção de grãos, envolvendo pastagens sob plantio direto. Rev. Cientifica Rural 9:23-31.
Spera ST, Santos HP, Fontaneli RS, Tomm GO (2009). Integração lavoura e pecuária e os atributos físicos de solo manejado sob sistema plantio direto. R. Bras. C. Solo 33:129-136. http://dx.doi.org/10.1590/S0100-06832009000100014
Spera ST, Santos HP, Fontaneli RS, Tomm GO (2012). Efeito de sistemas de integração lavoura-pecuária sob plantio direto em alguns atributos físicos do solo. Rev. Brasil. de Ciências Agrárias 7:388-393. http://dx.doi.org/10.5039/agraria.v7i3a1227
Stolf R (1991). Teorias e testes experimentais de fórmulas de transformação dos dados de penetrômetro de impacto em resistência do solo. R. Bras. C. Solo 15:229-235.
Tavares-Filho J, Feltran CTM, Oliveira JF, Almeida E (2012). Modelling of soil penetration resistance for an Oxisol under no-tillage. R. Bras. C. Solo 36(1):89-95. http://dx.doi.org/10.1590/S0100-06832012000100010
United States Department of Agriculture – USDA (1993). Soil survey manual. Washington D.C, USA, Soil Survey Division Staff, USDA Handbook 18, 437 pp.
Viana ET, Batista MA, Tormena CA, Costa ACS, Inoue TT (2011). Atributos físicos e carbono orgânico em Latossolo Vermelho sob diferentes sistemas de uso e manejo. R. Bras. C. Solo 35:2105-2114. http://dx.doi.org/10.1590/S0100-06832011000600025
Williams SM, Weil RR (2004). Crop cover root channels may alleviate soil compaction effects on soybean crop. Soil Sci. Soc. Am. J. 68:1403-1409.

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Full Length Research Paper

Effects of organic and inorganic soil amendments on growth performance of plantain (*Musa paradisiaca* L.)

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A field experiment was conducted to investigate the comparative effects of organic and inorganic soil amendments on growth and performance of plantain (*Musa paradisiaca*). The experiment was established in March 2011 and repeated in February 2012. The treatments consisted of nine soil amendments (NPK sole, Jatropha sole, palm kernel cake (PKC) residue sole, Sunshine organo-mineral sole, NPK + Jatropha husk 50:50, Sunshine organo-mineral + Jatropha husk 50:50, PKC residue + NPK 50:50, PKC residue + Sunshine organo-mineral 50:50, and Control) experiment was laid out in a randomized complete block design, and replicated thrice. No significant (P < 0.05) difference obtained in the two trials, nevertheless, NPK 15:15:15 produced the highest response to leaf area, leaf numbers and stem girth. Sunshine organo-mineral also showed higher response in stem girth, while the combination of decayed Jatropha husk and NPK fertilizer applied at the ratio of 50:50 had the highest plant height. To facilitate the scaling up of these fertility options, future research and development needs to address recommended application rates, impacts and the method by which crops can be intensively farmed to provide a natural progression out of poverty. Sustaining the findings of this research will enhance good soil management quality, increase farmers productivity as well as improves farmer's standard of living.

Key words: Fertilizers, growth parameters, organo-mineral, plantain and soil amendments.

INTRODUCTION

Plantain is a major food in Equatorial Africa and Andean regions (USDA, 2009). The attractiveness as food is that they fruit all year round; making plantain all reliable more season stable food. Plantain is grown as a rain fed crop in Nigeria. Its production is limited as it is committed mostly in the hands of subsistence farmers, who cultivate plantain to protect or shield other crops such as cocoa (*Theobroma cacao*) at the early stage of their vegetative growth to prevent cacao from wilting due to low soil moisture experienced in the dry season. Plantain production in Nigeria has been estimated to be 1,855,000 metric tonnes and they are produced in large quantities in Edo, Delta, Ogun, Ondo, Oyo, Osun, Rivers, Cross River, Imo, Anambra, Lagos, Kwara, Benue, Plateau, Kogi, Abia and Enugu states (Wilson, 1983; Swennen, 1990; FAO, 1997). In Nigeria plantation production has gone seriously on the decline due to diseases (Ramsey et. al., 1990), depleted soil nutrients and inadequate and

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indiscriminate use of soil amendments (Rosati et al., 2000).

Soil nitrogen mineralization and availability has a direct and significant influence on plant vitality, which has been highly depleted (Rosati et al., 2000).

Soils in South Western and Southern part of Nigeria where plantain are mostly cultivated are acidic due to the nature of the parent material, heavy leaching and weathering. In addition to acidity, the soils suffer from nutrient deficiency (Owolabi et al., 2003). Plantain requires deep and fertile soil which contributes to rapid leaf production and optimum nutrient uptake (Obiefuna, 1984). Also, late flowering has been attributed to low soil fertility status. Bunch mass and yield component of plant and ratoon crops except the number of hands per bunch respond to potassium, phosphorus and nitrogen at various levels (Obiefuna, 1984).

Efficient soil management through organic and inorganic soil amendments, crop rotation, planting cover crops will boost further production and overcome hazardous practices on the soil from the environment such as bush burning and overgrazing. Yield increases can be attributed to soil quality improvements, including increased soil organic matter and water-holding capacity, better soil structure and water infiltration, and decreased erosion compared to continuous cropping or even following green manure cover crops (Wright et al., 2002). Soil amendments has improved the quality of arid and non-farming soils to cultivable land, soil structure of soils are improved through organic fertilizers used as soil amendment which increase the activities of micro and macro organisms in soil types, thus improves soil formation through increasing organic matter content in soils, structure and aeration. Many long-term studies in the United States have documented trends of organic matter losses on agricultural land (NRCS Soil Quality Institute, 2001). Land degradation and declining soil fertility are increasingly being viewed as critical problems affecting agricultural productivity and human welfare in tropical Africa. It is estimated that an average of 660 kg of nitrogen (N) ha^{-1}, 75 kg of phosphorus (P) ha^{-1} and 450 kg of potassium (K) ha^{-1} have been lost during the last 30 years from around 200 million ha of cultivated land in 37 countries in sub-Saharan Africa (SSA) (Stroorvogel et al., 1993). Past long-term experimental studies have shown that soil organic C (SOC) is highly sensitive to changes in land use, with changes from native ecosystems such as forest to agricultural systems almost always resulting in a loss of SOC (Jenkinson, 1977; Paul et al., 1997). Likewise, the way in which land is managed following land use change has also been shown to affect SOC stocks. We therefore have the opportunity in the future to change to land use and land management strategies that lead to C storage in the soil, thereby mitigating GHGs effects and improving soil fertility. The critical issue for improving agricultural productivity in southern Africa is how to build up and maintain soil fertility despite low incomes, increasing labour and land constraints faced by smallholder farmers (Kumwenda et al., 1997).

Smallholder farmers in Nigeria have adopted high yielding plantain varieties and other crops such as maize, cassava and grain legumes with some success. However, increase in crop growth and yields have been disappointing. This is largely as a result of declining soil fertility among many other factors. This problem is widespread and is becoming worse with market liberalization in Nigeria. Most nutrient budgets show a negative balance due to soil nutrients deficiencies, which are used up by other crops initially grown on the land or by leaching and little use of inorganic fertilizer and organic inputs. The question to be posed is how to build up and maintain soil fertility under the poverty faced by many farmers. The need for added external nutrients is imperative. However, inorganic fertilizers are expensive; their use is sometimes unprofitable especially because of blanket recommendations. As a result, farmers need to be enhanced to produce a basic stable crop like plantain more efficiently putting into cognizance soil quality improvement and also improve on the constraints and possible areas of conservation towards a greater plantain output. Therefore, comparative effects of organic and inorganic soil amendments was carried out on growth performance of plantain and the variation in the treatments used was determined in order to recommend best soil amendments that could be used to boost plantain production and conserve soil nutrients for further crop production.

MATERIALS AND METHODS

Experimental design

The following experiments was laid out in a randomized complete block design and replicated thrice. Nine plantain suckers (corms) were planted at a spacing of 3 x 3 m per plot, ultimately a total plant population of eighty-one was established in 729 m^2 land area.

Treatments

The nine treatments used were derived from both organic and inorganic sources. The organic fertilizer used included sunshine organo– mineral (fortified) and other organic manures derived from Jatropha husk, palm kernel cake residue. Meanwhile, the inorganic fertilizer used was NPK fertilizer (15:15:15). Weeding was done manually four times at four, eight, twelve and fifteenth week after planting. The treatments were arranged as follows:

(1) NPK 15:15:15 sole
(2) Sunshine organo – mineral sole
(3) Palm kernel cake sole (residue)
(4) Jatropha husk sole (Decaying)
(5) Jatropha husk + sunshine organo- mineral (50:50)
(6) Jatropha husk + NPK (50:50)
(7) Palm kernel cake (PKC) (residue) + sunshine organo- mineral (50:50)
(8) Palm kernel cake (residue) + NPK (50:50)
(9) Control

Figure 1. A selected plant with inorganic soil amendment (NPK15:15:15, sole).

Fertilizer application

Placement method of fertilizer application adopted in this study involves placing fertilizers at a safe distance from where the root system of the crops is able to make use of it (Figure 1). Nine varied treatment combinations and quantity of fertilizer and manure were applied (Table 1).

Criteria used in the selection of crop experimental variety

(1) Early maturing
(2) Moisture stress resistance
(3) High yielding
(4) Pests and diseases free
(5) Average weight of corms (250 g)

Data collection and analysis

Primary data were collected starting at sixth week after planting which is equivalent to 4 weeks of growth before fertilizer application and 2 weeks for mineralization after its application. The growth parameters measured included, stem girth, number of leaves, leaf area and plant height. Data was collected from each experimental plot two weeks after treatment application and at intervals of two weeks up to the 16th week. Treatment effect were determined by analysis of variance (ANOVA) and significant mean differences were separated using Tukey at $P \leq 0.05$.

RESULTS

There was a significant effect on the growth parameter in the soil amendments used at $P \leq 0.05$ (Tables 2 to 5). The mean difference among the parameters showed significant effect at $P \leq 0.05$.

Comparison of means of number of leaves (NL)

NPK 15:15:15 as a treatment showed the highest number of leaves among other treatments selected (Table 2). There was significant difference between the 'numbers of leaves' as a growth parameter considered on plants and the source of fertilizers used. This result was taken from number of leaves (fresh and dry) produced by plantain plant during the experiment.

Comparison of means on the stem girth of plantain plants

NPK 15:15:15 and sunshine organo-mineral soil treatments showed a better response in stem girth from 2 to 14 weeks of application. But sunshine organo-mineral showed a higher response (52.13 cm) than NPK at 16th week of application (Table 3).

Comparison of means on leaf area (cm^2) of the sampled plantain plants

The wide and vigorous growth of leaves observed in Sunshine organo-mineral sole and NPK 15:15:15 sole produced by plants, exposed the plants to more area of photosynthesis and as a result helps in the vigorous growth of other parts of plant (Table 4).

Table 1. Treatments combination and quantity of fertilizer and manure applied.

Treatments	Quantity applied/stand	Quantity applied/ha
	grammes	kilogramme
NPK 15:15:15 sole	180	200
Sunshine organo-mineral sole	226	250
PKC sole (residue)	361	400
Jatropha husk sole	361	400
Jatropha husk + Sunshine organo-mineral (50:50)	294	325
PKC residue + sunshine organo-mineral (50:50)	294	325
Jatropha husk + NPK (50:50)	271	300
PKC residue + NPK (50:50)	271	300
Control (no fertilizer application)	0	0

Table 2. Effects of organic and inorganic soil amendments on number of leaves.

Treatments	2	4	6	8	10	12	14	16
	Weeks after treatments application							
Control	6.00^{cd}	7.00^{de}	7.33^{de}	8.33^{de}	9.33^{de}	9.67^{d}	10.67^{cd}	11.33^{de}
PKC residue + NPK (50:50)	4.67^{d}	5.67^{e}	6.67^{e}	7.67^{e}	8.67^{e}	9.33^{d}	10.00^{d}	10.67^{e}
Jatropha husk sole	7.33^{bc}	8.00^{cde}	8.67^{cde}	9.33^{cde}	10.33^{cde}	11.00^{cd}	11.67^{cd}	12.67^{cde}
PKC residue sole	8.00^{abc}	9.67^{bc}	10.67^{bc}	11.33^{bc}	12.33^{bc}	13.00^{bc}	13.33^{bc}	14.33^{bc}
Jatropha husk + Sunshine Organo-mineral (50:50)	8.00^{abc}	8.67^{bcd}	9.67^{bcd}	10.67^{bc}	11.67^{bcd}	11.67^{cd}	12.67^{bcd}	13.67^{bcd}
PKC residue + Sunshine organo-mineral (50:50)	7.67^{abc}	8.67^{bcd}	9.67^{bcd}	10.33^{cd}	11.33^{bcd}	11.67^{cd}	12.67^{bcd}	13.67^{bcd}
Jatropha husk + NPK (50:50)	7.67^{abc}	8.67^{bcd}	9.33^{bcd}	10.33^{cd}	11.33^{bcd}	12.33^{bc}	13.00^{bc}	14.00^{bcd}
Sunshine organo-mineral sole	9.33^{ab}	10.67^{ab}	11.67^{ab}	12.67^{ab}	12.33^{ab}	14.33^{ab}	15.00^{ab}	15.67^{ab}
NPK sole	10.00^{a}	12.33^{a}	13.33^{a}	14.33^{a}	15.67^{a}	16.33^{a}	17.00^{a}	17.33^{a}

Means followed by the same column are not significantly different from each other by Tukey at 5% level of probability.

Table 3. Effects of organic and inorganic soil amendments on stem girth development

Treatments	2	4	6	8	10	12	14	16
	Weeks after treatments application							
Control	10.33^{c}	17.37^{c}	20.07^{e}	23.03^{e}	26.07^{d}	29.00^{d}	31.37^{d}	34.10^{e}
PKC residue + NPK (50:50)	12.00^{bc}	18.07^{bc}	21.00^{de}	25.03^{de}	28.67^{cd}	33.00^{cd}	37.43^{c}	41.67^{cd}
Jatropha husk sole	14.67^{abc}	20.07^{bc}	23.37^{cde}	29.03^{cd}	33.67^{bc}	38.00^{bc}	42.37^{bc}	45.67^{cd}
PKC residue sole	15.00^{abc}	19.00^{bc}	22.73^{cde}	28.00^{cde}	32.10^{bc}	35.00^{bc}	40.33^{bc}	45.33^{cd}
Jatropha husk + Sunshine organo-mineral (50:50)	15.00^{abc}	21.07^{abc}	25.37^{bcd}	29.33^{cd}	33.07^{bc}	37.67^{bc}	41.00^{bc}	43.33^{cd}
PKC residue + Sunshine organo-mineral (50:50)	17.33^{ab}	23.67^{ab}	26.67^{abc}	31.40^{abc}	35.67^{b}	39.67^{ab}	43.33^{b}	46.67^{bcd}
Jatropha husk + NPK (50:50)	17.40^{ab}	22.73^{abc}	26.07^{abcd}	31.00^{bc}	35.33^{b}	40.37^{ab}	44.10^{ab}	47.70^{abc}
Sunshine organo-mineral sole	18.03^{ab}	26.13^{a}	30.00^{ab}	35.00^{ab}	41.43^{a}	44.43^{a}	48.67^{a}	52.13^{a}
NPK Sole	18.47^{a}	26.67^{a}	31.10^{a}	36.40^{a}	41.43^{a}	44.77^{a}	48.67^{a}	51.87^{ab}

Means followed by the same column are not significantly different from each other by Tukey at 5% level of probability.

Comparison of means on Plant height (cm) of the sampled plantain plants

Jatropha husk + NPK 15:15:15 (50:50) and NPK 15:15:15 sole, produced a better response in terms of plantain plant height at (160 and 172 at 16 weeks respectively). Higher levels of phosphorus derived from both organic and inorganic sources in Jatropha and NPK was noted to be responsible for higher response in the height of plants as realized in the study (Table 5 and Figure 2).

Table 4. Effects of organic and inorganic soil amendments on Leaf area of plants

Treatments	2	4	6	8	10	12	14	16
	Weeks after treatment application							
Control	772.7^{b}	1343.0^{c}	2098.3^{b}	2757.7^{cd}	2681.3^{d}	4269.3^{c}	5110.3^{b}	6024.0^{cd}
PKC residue + NPK (50:50)	828.7^{b}	1198.0^{c}	2082.3^{b}	2706.7^{d}	3265.7^{cd}	3946.0^{c}	4689.7^{b}	5347.7^{d}
Jatropha husk sole	1285.3^{ab}	1928.7^{bc}	2813.3^{b}	3666.7^{bcd}	4393.0^{bcd}	5277.0^{bc}	6302.3^{b}	6968.7^{bcd}
PKC residue sole	1789.0^{ab}	2542.0^{abc}	3147.0^{b}	4420.3^{bc}	6335.7^{ab}	6814.0^{b}	8191.0^{ab}	9191.7^{b}
Jatropha husk + Sunshine Organo-mineral (50:50)	1719.0^{ab}	2282.0^{abc}	3310.0^{b}	4120.3^{bcd}	4769.3^{bcd}	5737.0^{bc}	6622.0^{b}	7244.7^{bcd}
PKC residue + Sunshine organo-mineral (50:50)	1894.7^{ab}	2378.0^{abc}	3520.7^{b}	4642.3^{b}	5427.0^{bc}	6096.0^{bc}	5236.0^{b}	8377.3^{bc}
Jatropha husk + NPK (50:50)	1894.7^{ab}	2554.7^{abc}	3561.3^{b}	4741.7^{b}	6025.3^{b}	7115.3^{b}	8140.7^{ab}	9371.0^{b}
Sunshine organo-mineral sole	2423.3^{a}	3621.7^{ab}	5506.7^{a}	6754.7^{a}	8368.7^{a}	10233.7^{a}	11413.0^{a}	12494.0^{a}
NPK Sole	2567.3^{a}	3945.3^{a}	5815.0^{a}	6687.7^{a}	8557.0^{a}	10360.7^{a}	11586.0^{a}	12406.7^{a}

Means followed by the same column are not significantly different from each other by Tukey at 5% level of probability.

Table 5. Effects of organic and inorganic soil amendments on plant height.

Treatments	2	4	6	8	10	12	14	16
	Weeks after treatments application							
Control	51.33^{b}	59.67^{a}	76.67^{a}	89.00^{c}	99.00^{b}	107.67^{b}	117.67^{c}	126.00^{c}
PKC residue + NPK (50:50)	51.00^{b}	66.00^{ab}	88.00^{ab}	96.33^{bc}	96.33^{bc}	117.00^{ab}	127.67^{bc}	136.00^{bc}
Jatropha husk sole	56.00^{ab}	72.67^{ab}	89.33^{ab}	102.33^{abc}	111.67^{ab}	122.33^{ab}	133.33^{abc}	144.33^{abc}
PKC residue sole	50.67^{b}	68.33^{ab}	89.00^{ab}	05.33^{abc}	133.33^{ab}	121.67^{ab}	133.00^{abc}	143.67^{abc}
Jatropha husk + Sunshine Organo-mineral (50:50)	54.67^{ab}	70.33^{ab}	89.67^{ab}	104.33^{abc}	115.67^{ab}	124.67^{ab}	132.33^{abc}	140.67^{bc}
PKC residue + Sunshine organo-mineral (50:50)	77.67^{ab}	88.67^{ab}	102.33^{ab}	117.00^{abc}	127.67^{ab}	136.67^{ab}	147.67^{abc}	157.00^{ab}
Jatropha husk + NPK (50:50)	87.67^{a}	101.67^{a}	117.67^{a}	126.00^{ab}	134.33^{ab}	142.00^{a}	150.00^{ab}	160.67^{ab}
Sunshine organo-mineral sole	59.33^{ab}	83.33^{ab}	107.00^{ab}	15.00^{abc}	125.00^{ab}	133.33^{ab}	142.00^{abc}	154.00^{abc}
NPK Sole	76.67^{ab}	101.67^{a}	121.33^{a}	134.33^{a}	142.67^{a}	149.00^{a}	158.33^{a}	172.33^{a}

Means followed by the same column are not significantly different from each other by Turkey at 5% level of probability.

DISCUSSION

There was a significant comparative effect of organic and inorganic soil amendments on the growth performance of plantain in this study. NPK 15:15:15(treatment) showed a better response in stem girth, number of leaves and leaf area. NPK + Jatropha gave more significant effect on plant height; this confirmed the observation made by Swift et al. (1994) that combination of organic matter and fertilizer improved growth performance of crop when maintained without degrading soil fertility status. This observation was also made by Obiefuna (1984) that plantain vigorous growth could be attributed to mulching and nutrient uptake. Also faster rate of mineralization of the NPK treatment in the soil before others aided the fast uptake by plants taking the nutrients added, in

Figure 2. A selected plant with organic soil amendment (sunshine organo-mineral plus decaying Jatrofa husk 50:50).

a bottom-up manner for growth and development. This support the observation of Metcalfe and Elkins (1984), that nitrogen fertilization enhanced water use efficiency of a crop. This resulted in higher yield at harvest season. The applied nitrogen might have enhanced water uptake by the suckers which was utilized for growth efficiency. Downton (1983) also observed that availability of nitrogen source to plants roots facilitates and encourages osmo-regulation in the leaves such that the leaves did not suffer photosynthetic inhibition.

The fortified 'sunshine organo-mineral' which was made up of decayed organic matter has higher moisture absorbing character, thus water is absorbed from the environment to the root zone of plants which correlated with the observation of Crafts (1968), that the supply of nutrients to a plant is directly related to water movement into roots. Also Ndubuzi and Okafor (1976) earlier reiterated the importance of moisture availability on leaf production in plantain. This character established a more competitive association between NPK and 'sunshine organo-mineral'. It was deduced from this study that soil amendments using both organic and inorganic sources aided the growth performance of plantain especially after 4 to 8 weeks of application.

Conclusion

It could be deduced from this study that the application of nutrients supplements as soil amendments enhanced the growth of plantain resulting in rapid leaf production and plant vigour. However, NPK 15:15:15 fertilizer sole, showed the highest level of response to agronomic growth performance of plantain while 'sunshine organo-mineral' and combination of decayed Jatropha husk + NPK fertilizer also had a significant contribution. In addition, the soil amendments might have improved the soil quality through the increase in available soil nutrients to plants. The solution to soil fertility problems will not depend on use of inorganic fertilizers alone. More attention should be directed to the use of organic and inorganic sources and the combination of both for better soil quality improvement. Therefore it is highly suggestive that the usage of soil amendments such as NPK 15:15:15 fertilizer, 'sunshine organo-mineral' and combination of decayed Jatropha husk + NPK fertilizer will boost plantain production tremendously and soil fertility level to further plantain production. The paradigm of research and development on soil fertility options must change. The approaches need to move from rigid and prescriptive approach to flexible, problem solving format with a lot of farmer participation. There is need for social science research to deal with issues of adoption and scaling up of the available options. Potential synergies to address soil fertility problems can be gained by combining technical options with farmer's knowledge as well as new approaches to farmer training and policy dialogue. Policy issues touching on the soil resource base, as well as product markets need to be addressed to ensure use of agricultural technological innovations.

Conflict of Interest

The authors have not declared any conflict of interest.

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REFERENCES

Crafts AS (1968). Water deficit and physiological process. In: Water Deficit and Plant Growth. Vol 11. Kozlowski TT (Ed.). Academic Press, N.Y. pp. 85-124.

Downton WJS (1983). Osmotic adjustment during water stress protects the photosynthetic apparatus against photo inhibition. Plant Sci. Lett. 30:137-143.

Food and Agriculture Organization of the United Nations FAO (1997). FAO production Statistics (FAO) and the Information Network on Post-harvest Operations (INPhO). P. 198 FAO Code: 86, AGRIS: SO1, ISBN 92-5-102862-1.

Jenkinson DS, Rayner JH (1977). The turnover of soil organic matter in some of the Rothamsted Classical Experiments. Soil Sci. 123:298-305.

Kumwenda JDT, Waddington S, Snapp SS, Jones JB, Blackie MJ (1997). Soil fertility management in the smallholder maize based cropping systems of eastern and southern Africa. In Eisher C (eds) The Emerging Maize Revolution. Michigan State University E. Lansing, MI, USA, pp. 153-172.

Metcalfe DS, Elkins DM (1984). Crop Production: Principles and Practices. 4th Edition. Macmillan Pub. Co., Inc. N.Y. P. 774.

Ndubuzi TOC, Okafor EI (1976). Growth and yield pattern of Nigeria plantains. Fruit 31:672-677.

NRCS Soil Quality Institute (2001). Soil quality – agronomy technical note no. 12: Long-term agricultural management effects on soil carbon. United States Department of Agriculture, Natural Resources Conservation Service. Available online at http://soils.usda.gov/sqi (verified 9 Jun12).

Obiefuna JC (1984). Effects of delayed fertilizer application on the growth and yield of plantains in South Western Nigeria. Fertilizer Res. 5:309-313.

Owolabi O, Adeleye A, Oladejo BT, Ojeniyi SO (2003). Effect of wood ash on soil Fertility and crop yield in southwest Nigeria. Nig. J. Soil Sci. 13:55-60.

Paul EA, Paustian K, Elliott ET, Cole CV (1997). Soil Organic Matter in Temperate Agroecosystems. CRC Press, New York. P. 432.

Ramsey MD, Daniels JW, Anderson VJ (1990). Effects of *Sigatoka* leaf spot (*Mycophaerellamusicola* leach) on fruit yields, field ripening and green life of banana in North Queenland. Scientia Hortic. 41:305-313.

Stroorvogel JJ, Smaling EMA, Janssen BH (1993). Calculating soil nutrient balances in Africa. I. Supranational scale. Fertilizer Res.35:227-235.

United States Department of Agriculture, (USDA) Database (2009). Health benefits of Plantain, J. Educ. Res. pp. 31-34.

Rosati A, Day KR, DeJong TM (2000). Distribution of leaf massper unit area and leaf nitrogen concentration determine partitioning of leaf nitrogen within tree canopies. Tree Phys. 20:271-276.

Swennen R (1990). "Plantain Cultivation Under West Africa Conditions, A Reference Manual. International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. P. 24.

Swift MJ, Seward PD, Frost PGH, Qureshi JN, Muchena FN (1994). Long term experiments in Africa: developing a database for sustainable land use under global change. In Leigh RA, Johnson AE (eds), Long term Experiments in Agricultural and Ecological Sciences, pp. 229-251.

Wilson GF (1983). Plantain Production: Prospects for improving the food situation on the Tropics*"*. Fruits 38(4):229-239.

Wright DL, Marois JJ, Wiatrak PJ (2002). Perennial forage in rotation with row crops in the Southeast. In E. van Santen (ed.), Making conservation tillage conventional: Building a future on 25 years of research. Proceedings of 25th Annual Southern Conservation Tillage Conference for Sustainable Agriculture. Auburn, AL 24–26 June 2002. Special Report No.1. Alabama Agric. Expt. Stn. and Auburn University, AL. pp. 87-92. http://www.ag.auburn.edu/nsdl/sctcsa/sctcsa_2002/proceedings.html.

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